Climate Change in the Western Cape:
A Disaster Risk Assessment of the Impact on Human Health

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Author's declaration

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree

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Abstract

Background

The Disaster Management Act (Act 57 of 2002) instructs a paradigm shift from preparedness, response and recovery towards risk reduction. In order to plan for and mitigate risks, all spheres of government must firstly assess their hazards, vulnerabilities, capacity to cope and therefore risks. Studies in this regard, in South Africa, have however only focussed on current risks. Climate Change has now been accepted by leading international studies as a reality. Climate change can impact upon many aspects of life on earth. Studies to quantify the impact of climate change on water resources, biodiversity, agriculture and sustainable development are steadily increasing, but human health seem to have been neglected. Only general predictions, mostly regarding vector-borne disease and injury related to natural disasters are found in literature. Studies in South Africa have only focussed on malaria distribution. Most studies, internationally and the few in South Africa, were based on determining empirical relationships between weather parameters and disease incidence, therefore assessing only the hazard, and not the disaster risk.

Methodology

This study examines the impact of climate change on human health in the Western Cape, within the context of disaster management. A qualitative approach is followed and includes:

- A literature overview examining predicted changes in climate on a global and regional scale,
- A discussion on the known relationships and possible impacts climate change might have on human health,
- A disaster risk assessment based on the status quo for a case study area, the Cape Winelands District Municipality,
- An investigation into the future risks in terms of health, taking into account vulnerabilities and secondary impacts of climate change, resulting in the prioritisation of future risks.
- Suggestions towards mitigation within the South African context.

Results

The secondary impacts of climate change were found to have the larger qualitative impact. The impact of climate change on agriculture, supporting 38% of the population can potentially destroy the livelihoods of the workforce, resulting in poverty-related disease.

Other impacts identified were injuries and disease relating to temperature, floods, fire and water quality.

Conclusion

Risk is a function of hazard, vulnerability and capacity to cope. The impact of an external factor on a ‘spatial system’ should be a function of the impacts on all these factors. Disasters are not increasing because of the increase in the frequency of hazards, but because of the increasing vulnerability to hazards. This study illustrated that the major impacts of the external factor could actually be on the vulnerabilities and the indirect impacts, and not on the hazard itself. Climate change poses a threat to many aspects of the causative links that should be addressed by disaster management, and its impacts should be researched further to determine links and vulnerabilities. This research also illustrates that slow onset disasters hold the potential to destroy just as much as extreme events such as Katrina, Rita or a tsunami. It also reiterates that secondary impacts may not be as obvious, but are certainly not of secondary importance.

Opsomming

Agtergrond

Die Rampbestuurwet (Wet 57 van 2002) vereis ‘n paradigma skuif vanaf gereedheid en reaksie na risiko vermindering. Om risiko’s te verminder, is dit nodig om die gevare, kwesbaarhede, die vermoë om dit te hanteer en dus die risiko’s van ‘n area te ondersoek. Studies van hierdie aard in Suid Afrika het egter tot op datum hoofsaaklik gefokus op bestaande risiko’s. Klimaatsverandering word egter gesien as ‘n realiteit deur die internasionale gemeenskap. Klimaatsverandering kan die lewe op aarde op verskeie maniere beinvloed. Navorsing om impakte op areas soos biodiversiteit, waterbronne en landbou te ondersoek raak al hoe meer. Die impak op menslike gesondheid is egter tot op datum afgeskeep, en is beperk tot die impak op vektor gedraagde siektes en beserings gedurende natuurrampe. Studies in Suid Afrika is min en beperk tot die verspreiding van malaria. Hierdie studies poog meestal om die empiriese verwantskap tussen weer en siekte insidensie te bepaal, en fokus dus op die rampgevaar en nie die risiko as sulks nie.

Metodologie

Hierdie studie ondersoek die impak van klimaatsverandering op menslike gesondheid in die Weskaap, binne die rampbestuuromgewing. ‘n Kwalitatiewe benadering word gevolg, en sluit die volgende aspekte in:

- ‘n Literatuuroorsig na die klmaatsverandering fenomeen op’ n globale en streeksvlak,
- ‘n Bespreking van die bekende verwantskappe tussen klimaatsverandering en gesondheid.
- ‘n Ramp-risiko analise gebasseer op die status quo vir die gevallestudie, die Kaapse Wynland Distriksmunisipaliteit,
- ‘n Ondersoek na die toekomstige risiko’s, in terme van gesondheid, wat die sekondêre impakte van klimaatsverandering en die kwesbaarhede in ag neem,
- Voorstelle vir risikovermindering binne die Suid Afrikaanse rampbestuur konteks.

Resultate

Die sekondêre impakte van klimaatsveranderinge het die grootste impak op gesondheid. Die impak op landbou, wat direk werk verskaf aan 38% van die bevolking, kan hul lewensbestaan ernstig affekteer, wat ‘n verhoging in armoede-verwante gesondheidsprobleme sal veroorsaak. Ander

impakte wat geïdentifiseer is sluit in beserings en siektes wat verband hou met temperatuur, vuur, vloede en waterkwaliteit.

Opsomming

Risiko is ‘n funksie van gevaar, kwesbaarheid en vermoë om dit te hanteer. Die impak van ‘n eksterne faktor op ‘n sisteem behoort ‘n funksie te wees van die impak op al hierdie faktore. Rampe neem nie toe net omdat daar ‘n toename in gevare plaasvind nie, maar ook weens die toename in kwesbaarheid.

Hierdie studie illustreer dat die hoof impakte van ‘n eksterne faktor die ramp-risiko kan beïnvloed deur die impak op die kwesbaarheid of deur die indirekte impak, en nie op die gevaar self nie. Klimaatsverandering hou ‘n groot gevaar in vir baie aspkete van die oorsaaklike skakels wat deur rampbestuur aangespreek behoort te word. Die impakte hiervan behoort verder nagevors te word om hierdie verbande en kwesbaarhede te ondersoek. Hierdie navorsing illustreer ook dat ‘n ‘kruipende’ ramp net soveel skade as ‘n snelle aanset ramp soos Katrina, Rita of ‘n tsoenami. Verder illustreer dit dat sekondêre impakte dalk nie so ooglopend is nie, maar dat die geensins van sekondêre belang is nie.

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“There are risks and costs to a programme of action, but they are far less than the long-range risks and costs of comfortable inaction."

J.F. Kennedy.

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Glossary

Climate. The average weather over periods of longer than a month. (Appleton 2003)

Climate change. A change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. (Appleton 2003)

Climate variability. The range of values that the climate at a particular location can take over time. (Appleton 2003)

Disaster Risk Reduction. Disaster Risk Reduction is the science of reducing the risks to which vulnerable communities are being exposed. (UNISDR 2002)

Disaster. A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses that exceed the ability of the community or society to cope, using it's own resources. (UNISDR 2002)

Greenhouse gasses. Gaseous components of the atmosphere that contribute to the greenhouse effect. Some occur naturally in the atmosphere, while others are the result from human activities**.**

Hazard. A potentially damaging physical event, phenomenon or human activity, which may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. (UNISDR 2002)

Mitigation. Activities that prevent an emergency, reduce the chance of an emergency happening, or lessen the damaging effects of unavoidable emergencies. (UNISDR 2002). The Disaster management Act defines mitigation as 'measures aimed at reducing the impact of effects of a disaster'. (Republic of South Africa 2003)

Risk / Disaster Risk. The possibility, or chance, of harmful consequences, or expected loss (of lives, people injured, property, livelihoods, economies activity disrupted or environment damaged) resulting from interactions between natural and human-induces hazards and vulnerable conditions. (UNISDR 2002)

Vulnerability. Vulnerability refers to a set of conditions resulting from physical, social, economical and environmental factors, which increase the susceptibility of a community to the impact of a hazard. (UNISDR 2002)

Water-related disease.

The mechanisms by which water-related diseases are transmitted affect their impact on humans, animals and the environment. These mechanisms are classified as:

1. faecal-oral (water-borne or water-washed) for example diarrhoeal diseases, infectious hepatitis
2. water-washed only e.g. scabies, conjunctivitis
3. water-based e.g. trachoma, dracunculiasis
4. water-related but insect-vector transmitted, e.g. malaria, onchocerciasis.

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Abbreviations and Acronyms

AIDS	Acquired Immune Deficiency Syndrome
BRDSEM	Berg River Dam Spatial Equilibrium Model
CSAG	Climate Change Analysis Group
CWDM	Cape Winelands District Municipality
DMC	Disaster Management Centre
DPLG	Department of Provincial and Local Government
DWAF	Department of Water Affairs and Forestry
DTI	Department of Trade and Industry
ENSO	El Niño/Southern Oscillation
GCM	General Circulation Model
GDP	Gross Domestic Product
HIV	Human Immunodeficiency Virus
IDP	Integrated Development Plan
IMR	Infant Mortality Rate
IPCC	Intergovernmental Panel on Climate Change
GCM	General Circulation Model
MRC	Medical Research Council
NAO	North Atlantic Oscillation
NDA	National Department of Agriculture
NDMC	National Disaster Management Centre
RCM	Regional Circulation Model
RDP	Reconstruction and Development Programme
RSA	Republic of South Africa
SDF	Spatial Development Framework
SRES	Special Report on Emissions Scenarios
TB	Tuberculosis
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

UNISDR	United Nations International Strategy for Disaster Reduction
WHO	World Health Organisation
WMA	Water Management Area

CHAPTER 1

Setting the scene

1.1 Introduction

The state of our environment determines the level of our prosperity and wellbeing, now and for future generations. This reality has focused world attention to the diverse and interrelated factors of environmental conditions, socio-political circumstances and the health and wellbeing of people. For populations as well as regions it is crucial that capacity to cope with change be strengthened. This statement becomes even more profound, seen in the context of the overwhelming development needs of South Africa and the dependence of our society and economy on natural resources and properly functioning ecosystems (Department of Environmental Affairs and Tourism 2006)

Information on the impact of global changes in climate on water resources, biodiversity, agriculture and sustainable development is steadily increasing, but integrating these findings with human health seems to receive little research attention. Only general predictions, mostly regarding vector-borne disease and injuries related to natural disasters are found in the literature. Studies in South Africa linking climatic aspects with health have to date mostly focussed on possible changes in malaria distribution. These, as well as international studies, were based on empirical relationships between weather parameters and disease incidence, therefore assessing only the hazard, and not the disaster risk.

The risks involved in disasters are determined by our 'everyday' living conditions through the vulnerabilities created by such conditions (Wisner et al 2004). Disasters are therefore a complex mix of natural and other hazards and human action (and vulnerabilities). They consist of a combination of factors that determine the potential for people to be exposed to particular types of hazard. The impact of the disaster also depends fundamentally on how social and political systems interact in different societies. These factors determine how groups of people differ in relation to income (economy), health, employment, housing and social environment. This interdependency of social factors is illustrated in Figure 1.

Wisner et al (2004) explains the above web of causation by means of an example, the 1976 earthquake in Guatemala. The physical earthquake was a natural event, yet the poor, the slum dwellers in the towns and the Mayan Indians living under impoverished conditions suffered the highest mortalities. Earlier political and social regimes forced thousands of Mayans into settlements and onto marginal land and remote places. The homes of the members of the middle and upper income classes were better (more safely) situated, better constructed and covered by insurance which resulted in a better and quicker recovery. This is an excellent example of the relationship between society, hazard and disaster impact.

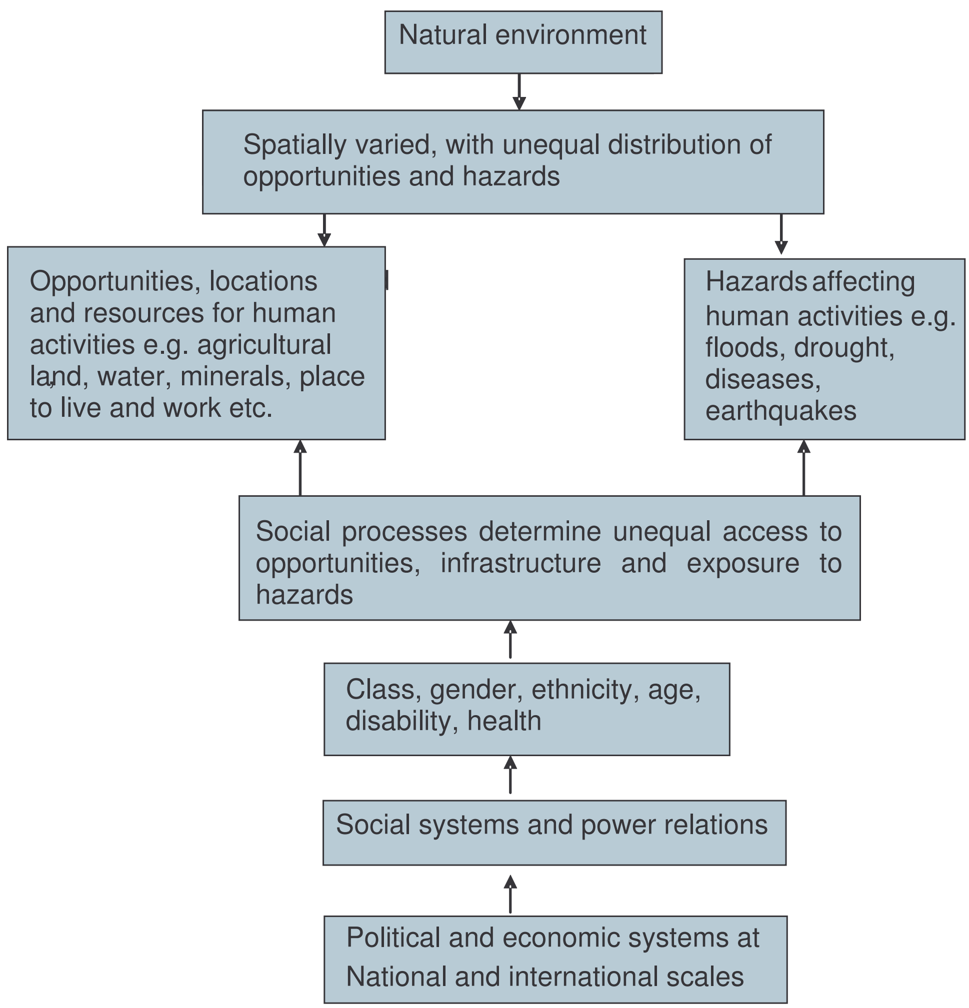

Figure 1: The social causation of disasters (adapted from Wisner et al 2004)

1.2 Health and wealth – a global overview

Health is regarded as a fundamental aspect of society, a key element of intrinsic human rights and justice (WHO 2005). It is a complex result of many impacting parameters. The next paragraphs summarises the health status quo, predictions for the future and examines climate change as an aggravating circumstance.

Health is considered “a central input to poverty reduction and socio-economic development” (WHO 2006a). The reverse cause-effect relationship is however also true. This inter-relationship can be summarised as two cycles, the first of which describes the relationship between poverty and health (WHO 2005). These are the so-called ‘vicious cycle’, acknowledging that poverty breeds ill-health and ill-health causes poverty, and the ‘victorious cycle’ recognizing that higher incomes are linked to good health and vice versa. Social, economic, environmental, institutional and political factors determine health outcomes and its distribution across social groups (WHO 2005). These factors, and therefore human health, vary temporally and spatially across the globe.

Life expectancy at age 15 has increased by two to three years over the last 20 years in most regions (WHO 2005). The improvement is generally attributed to an improvement in socioeconomic development and the provision of safe water and sanitation facilities which allows improved personal hygiene. About one third of the world’s population lives in countries suffering from water stress. One of the greatest environmental threats to health remains the continued use of untreated water (United Nations Environment Programme 2002). There are, however, widening health inequalities within and between countries and for different income groups and between genders and ethnical groups. HIV/AIDS exemplifies the challenge to the health sector: health concerns and actions reach far beyond medical care. Approximately 15% of deaths of 15-59 year olds in 2005 are attributable to AIDS, the leading mortality among adults of this age. Deaths from infectious diseases, perinatal, maternal and nutritional disorders have fallen form one third of total deaths in 1990 to one quarter in 2005. These deaths are “virtually all” (WHO 2005) recorded in low-income and middle-income countries. In 2005, 97% of child deaths occurred in low-income countries, half of which are in Africa. Communicable disease still causes 60% of chills deaths in Africa. In terms of environmental disease burden an estimated 24% of all deaths in children under 15 are due to environmentally-related diarrhoea, malaria and respiratory infections.

The United Nations reports that the world population is projected to peak at 9.22 billion in 2075 (United Nations 2004). From 2000 to 2100, the European contribution to the total population is said to decrease from 12% to 5.9%, while that of Africa increases from 13.1% to 24.9% (United Nations 2004). By 2100 the world population ought to be getting increasingly 'older' by current standards due to changes in fertility (birth) rates and life expectancy. A rapid increase in numbers of older people, estimated to be 300% by 2050, for both developing and developed countries is expected.

Southern Africa is expected to exhibit a decline of life expectancy to “a lower level than anywhere else”, but will eventually rise sharply to overtake that of other African regions. Africa is projected to enter the ‘demographic window’ (a period when the proportion of children under 15 years of age reach 30% and below, but the proportion of 65 year olds and older has not yet reached 15%) approximately around the year 2045, whereas Europe has already reached this window before 1950. This specific demographic window can also be more easily expressed as the dependency ratio for a population, calculated as follows (Gladwell 2006):

$$\mathbf{DR = [(\%\ persons <= 15 + \%\ persons > 65)/\ \%\ persons\ between\ 15\ and\ 64]\ X\ 100\%}$$

A developed country will typically have a lower dependency ratio than a developing country, due to a higher proportion of healthy adults in the 15 to 65 year old category and a low birth rate. Pakistan, a developing country, has a dependency ratio of 82%, whereas the figure for New Zealand is 54% due to a lower percentage of youths younger than 15 (Anon 2007). South Africa’s ratio has decreased from 64 in 1996 to 58 in 2006, varying drastically between provinces (Health Systems Trust 2007).

The data mentioned above illustrate basic demographic principles where the population pyramid of an area shows a decrease in births and age-related deaths as a society passes through demographic transition. Ultimately this continued trend in demographic transition would be an increased focus on age-related disease; chronic conditions such as diabetes, cancers, heart disease and dementia (WHO 2005). Chronic non-communicable diseases, including mental ill-health, currently represents 60% of the global disease burden. One quarter of the deaths occur in people below 60 years of age. Environmental factors, mostly related to air-pollution, cause over one third of the disease burden attributable to lower-respiratory tract infections. Lack of access to food and water are responsible for a “significant, but inadequately estimated” (WHO 2005) chronic disease burden related to chemical contamination of food and water sources in the low-income countries. Adult health is overall characterised by widening health gaps, the complexity of the disease burden and the spatial spread of health risk. Chronic disease and mental-ill health is also spreading to developing countries, already burdened by infectious disease and the HIV/AIDS pandemic. Both quality of life (morbidity) and life expectancy (mortality) is affected.

From the short discussion above it is evident that health is impacted upon by many factors and that it is related to wealth and therefore shelter and food security of a population. The statistics paints a bleak picture of current health, specifically in developing, lower income countries where the populations are much more vulnerable to any variations of the political, social and environmental systems. These countries are more vulnerable to external environmental triggers, since the direct impact would, amongst others, be on food security due to their reliance on agriculture as major contributor to their GDP. Low income, developing countries are therefore likely to experience a significant increase in food insecurity and hunger due to detrimental environmental changes, and their low adaptive capability (United Nations 2005). Climate change potentially poses a huge threat to an already vulnerable developing world (IPCC 1996, IPCC 2001, IPCC 2007, Downing et al 2001).

1.3 Climate Change : an aggravating circumstance

Modification of the physical and biological systems by human societies throughout history has lead to many social, economic and public health impacts. It has, however, also created new risks to health such as the mobilisation of infectious agents and the depletion of fresh water supplies (IPCC 2001, IPCC 2007, Schulze 2003). The clearing of the tropical rainforests is considered another example. Typically, such clearing leads to a warmer, drier climate with resulting drying of soil which may increase flood risk and greater volumes of runoff during periods of heavier or intense rainfall. Human life is consequently endangered through flooding, crop losses and a spatial and temporal change in vector-borne diseases.

As the scale of human impact accompanying a growing industrialised world increases, a range of health impacts can be expected from large-scale changes in the earth's 'life-support' (IPCC 1996, Appleton 2003). The rapid industrialisation of human society during the past 1000 years has significantly altered the gaseous composition of the earth's atmosphere and increasingly continues to do so (IPCC 1996, IPCC 2001, IPCC 2007, Midgley et al 2005, Sarukhan and Whyte 2005). The burning of fossil fuels for energy and the changes in land use and land cover increases the concentrations of the greenhouse gasses such as carbon dioxide and methane. These changes lead to global warming. It has become apparent that the concept of a 'current climate' is not appropriate. It has been confirmed that the changes in the composition of the atmosphere have begun to increase atmospheric and ocean temperatures, accelerate glacier and polar ice melt and have triggered shifts in the spatial and temporal distribution of some plant and animal species (IPCC 1996, IPCC 2001, Midgley et al 2005).

The previous brief overview illustrates that human health is a result of a complex inter-dependability. The appreciation of the impacts of environmental change on health requires a perspective that not only focuses on the direct impacts of climate change on disease, but also the impact on the earth's life-supporting systems as illustrated in Figure 2 (WHO 2006b). Health effects caused by impacts on other systems such as the environment, economic activities, urban and rural infrastructure and delivery of basic services, etc overshadow the few direct impacts of climate change on disease such as the often quoted changes in the endemicity of malaria. The direct impacts however constitute the prime focus of the majority of many current studies in medical geography.

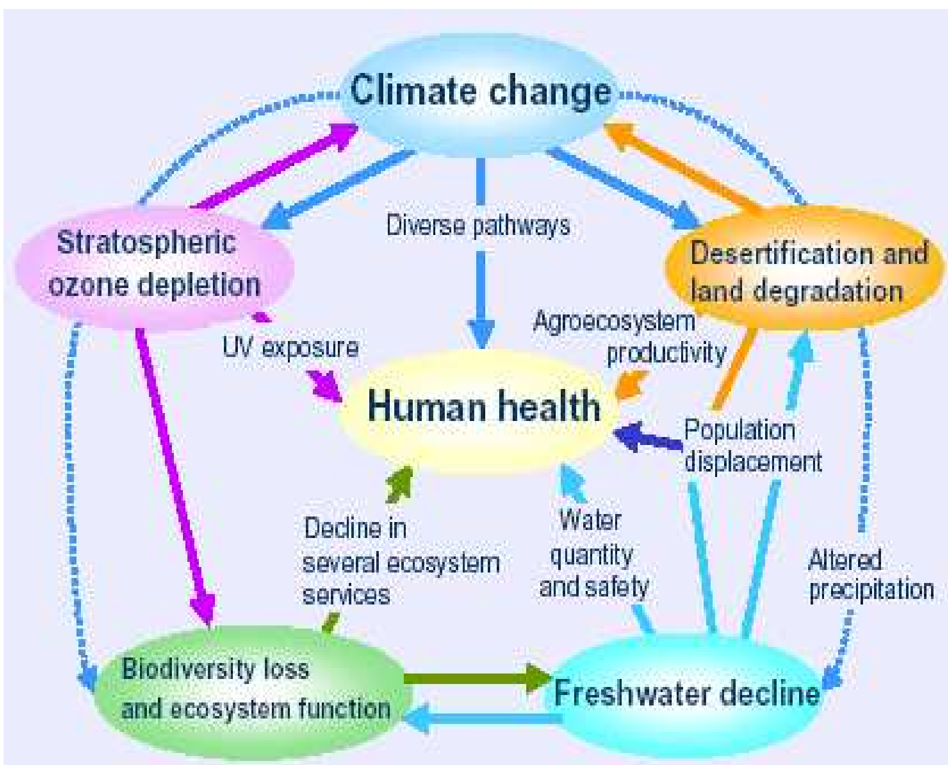

Figure 2: The complex inter-dependency of climate change and human health (WHO 2006b)

This figure illustrates a very recent, major mind-shift in assessing the impacts of climate change on human health, by recognising the inter-dependability of the many contributing factors. Assessing this situation from a disaster management perspective adds a sound conceptual framework.

1.4 The Disaster Management Perspective

The tsunami that ravaged the Indian Ocean coastline in December 2004 and the hurricanes Katrina and Rita that devastated the East Coast of the United States of America during 2005 once again focussed the world's attention on disasters. The massive scale of the loss of infrastructure, societal and emotional impact on communities, impacts on agriculture, loss of tourism revenue and economic hardship left the world in awe of the powers of nature. These highly publicised events contribute to the images many have of a disaster. Destroyed communities, towns or regions, debris, mass evacuations and a traumatised population are also normally associated with natural causes such as floods, tornadoes or earthquakes, or technological (man-made) events such as the terrorist attacks on the World Trade Centre. Very few, however, give credence to the threat of the unseen – a disaster that creeps up on a population and quietly destructs, often with serious secondary impacts.

Weather plays a major role either as a primary hazard or by exacerbating other hazards. Precipitation and temperature impact on runoff, irrigation, food security, biodiversity and health, the focus of this study (IPCC 1996, IPCC 2001, Schulze 2003, Schulze and Perks 2000, Kovats et al 2003).

Disasters have been studied for many years on a global scale, but those studies have mainly focussed on the frequency of occurrence, response and recovery and the primary impacts. In South Africa, the Disaster Management Act (Act 57 of 2002) (Republic of South Africa 2003) proceeds from the acceptance of a paradigm shift - from disaster response and recovery to disaster risk reduction and mitigation. All spheres of government (national, provincial and municipal) are instructed (section 47(1)) to constantly, amongst others, assess risks and vulnerabilities and engage in processes to prepare for and mitigate disasters. Risks and vulnerabilities are constantly changing spatially and temporally as the environment and demography of a region change. Current disaster risk assessments are however based on prevailing conditions and in most cases do not take the impacts of climate change into consideration. Climate change adds a new dimension to disaster risk assessment and preparedness planning.

1.5 Problem statement, aim and objectives

1.5.1 Problem statement

Direct assessments and predictions of the possible impacts of climate change on health are difficult to quantify due the diverse and extremely complex nature of disease transmission, human well-being and health-seeking behaviour. The majority of studies assessing the impacts of climate change on health are based on determining the empirical relationship between weather parameters and disease incidence, therefore assessing the hazard, and not the disaster risk. Assessing vulnerability in the area under consideration has however emerged as an important approach in assessing risk and is increasingly used to determine the likelihood of risk as well as the likely impact of any added stressors.

There are no simple fixes to the problems of climate change, biodiversity loss, land degradation, environmental pollution and deteriorating population health, to name a few. Furthermore, there are many uncertainties prevailing in our knowledge of the interface between health, climate and disaster risk. This study makes a first attempt at integrating these three disciplines.

1.5.2 Qualitative hypothesis

The status of the existing vulnerabilities in the Cape Winelands District Municipality is such that climate change (seen as an added stressor) will compromise the district's ability to cope and will aggravate future disaster risk.

1.5.3 Methodological framework

The methodology is based on the assessment of disaster risk within the context of the South African Disaster Risk Management legislation. The vulnerabilities of the population in the study area, concentrating on epidemiological data of human health, will also be assessed. Theoretical predictions for climate change and its probable impacts on human health, based on current understanding, will be interpolated on the existing disaster risk profile of the study area to qualitatively determine the impacts of climate change on disease. The impact of climate change on hazard and the resulting secondary impacts will be established, as well as the impact on the vulnerabilities contributing to risk. For a detailed discussion of the disaster risk assessment methodology, please refer to Chapter 3.

1.5.4 Aim and objectives

The overall aim of the present study is to identify the major impacts of climate change on human health in the Western Cape by examining the contribution of various systems conducive to total risk. The study will focus on the Cape Winelands District Municipality as a specific case study area. The analysis will be done within the context of disaster management, attempting to identify and illustrate the inter-dependability of many influencing factors and the complex feed-back mechanisms that exist.

The objectives are:

- To investigate the available theoretical models and state of scientific information regarding climate change and health and to and provide an overview of this information
- To give an overview of the South African disaster risk management legislation as a contextual framework for the study
- To examine the current disaster risk for the case study area and determine major threats
- To qualitatively assess the major risks to human health under a changed climate in the study area
- To identify and assess the social, economical and environmental vulnerability of the affected communities in the study area
- To determine the implications for policy and disaster management planning in the study area as well as nationally and to suggest risk reduction strategies.

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C H A P T E R 2

Disaster Risk Management

2.1 Disaster Risk Management concepts

The terms disaster, hazard and risk have already been referred to in previous paragraphs as they were used by various authors. Differing definitions may have been understood and used by these authors. Therefore, it is necessary to define what is understood by these terms. For the purpose of this study international definitions (UNISDR 2002), as defined below, will be used.

2.1.1 Definitions and terminology

Not all hazards leads to disasters and not all incidents are regarded as disasters. A ***hazard*** is a *potentially damaging* physical event, phenomenon or human activity, which *may* cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

A ***disaster*** is defined as a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses that *exceed the ability of the affected community or society to cope using its own resources*. The *possibility, or chance*, of harmful consequences, or expected loss (of lives, people injured, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions are termed the disaster ***risk***.

The saying "*prevention is better than cure*" has never been more applicable than in the case of disaster management (Botha and Louw 2004). ***Disaster risk reduction*** is seen as the science of reducing the risks to which vulnerable communities are being exposed through appropriate risk reduction measures.

Not all disasters impact directly on a community**.** The terms ***primary impact*** and ***secondary impact*** are used to describe the different causes and scales of potential impacts from a hazard event. Primary impacts are also called direct impacts, such as loss of housing through flooding. If an outbreak of disease such as cholera follows a flood, the cholera outbreak is then termed a secondary or indirect impact. A flood for instance can result in the malfunctioning or complete unavailability of sewage systems. Not only does this lead to the spreading of disease via untreated sewage, but it can also standing water which is conducive to mosquito breeding, given the right environmental conditions. This does not imply that ***secondary impacts*** are of secondary importance. In many cases the effects on biodiversity and the environment from secondary impacts are much more significant than those from primary impacts.

The impact of a disaster on a community is determined by the ***manageability, or capacity of a community to cope*** (that is the degree to which a community can intervene and manage the negative consequences of a hazard event), as well as the ***preparedness*** (readiness for the possibility of harmful consequences or expected loss) of the community. Whether a hazardous incident will be called / classified as a disaster will ultimately depend on the ***vulnerability*** of the community, which refers to a set of conditions resulting from physical, social, economical and environmental factors, which increase the susceptibility of a community to the impact of a hazard.

Disasters are not all natural. Previously, the terms 'natural' and 'man-made' were commonly used. It is however now a recognised practice to use the classification by the UNISDR (2002), as given below.

> **Natural hazards** are natural processes or phenomena occurring in the biosphere that may constitute a damaging event. Natural Hazards are typically classified into:

- **Geological Hazards**: Natural earth processes or phenomena in the biosphere, which include geological, neo-tectonic, geo-physical, geo-morphological, geo-technical and hydro-geological nature.
- **Hydro-meteorological Hazards**: Natural processes or phenomena of atmospheric, hydrological or oceanographic nature.
- **Biological Hazards**: Processes of organic origin or those conveyed by biological vectors, including exposure to pathogenic micro-organisms, toxins and bioactive substances.

Technological hazards are dangers originating from technological or industrial accidents, dangerous procedures or certain human activities, which may cause the loss of life or injury, property damage, social and economic degradation.

Environmental degradation encompass processes induced by human behaviour and activities (sometimes combined with natural hazards), that damage the natural resource base or adversely alter natural processes or ecosystems.

2.1.2 The South African legal framework

The South African National Government recognised a need to establish an institutional framework that allows for risk prevention and response during a disaster and has implemented the following:

The **White Paper on Disaster Management** introduced a new paradigm in the management of disasters, by placing an emphasis on risk reduction and preparedness.

The White Paper led to the promulgation of the **Disaster Management Act, Act 57 of 2002**, which is the regulatory framework for disaster management in South Africa. The Department of Provincial and Local Government (DPLG), through the National Disaster Management Centre (NDMC), administers this Act.

The NDMC has finalised the **National Disaster Management Framework,** which aims to guide the development and implementation of disaster management in the country.

The NDMC has also developed guidelines for the establishment of Disaster Management Centres (DMC's).

In general, the new South African Disaster Management Act (Act 57 of 2002) represents a paradigm shift from disaster preparedness to disaster risk reduction. This follows the international trend in which the United Nations International Strategy for Disaster Reduction declared the 1990's as the decade of risk reduction. The Act aims in its instructions to promote a culture of 'prevention rather than cure'. The paragraphs below summarises specific instructions for a municipal (district or local) entity.

The three spheres of government (national, provincial and district/metropolitan) must prepare ***Disaster Management Plans*** (Sections 39 and 53 of the Act).

Section 53 addresses the disaster management planning requirements for Municipal Entities, namely:

(1) Each municipality must, within the applicable municipal disaster management framework:

(a) prepare a disaster management plan for its area according to the circumstances prevailing in the area;

(b) co-ordinate and align the implementation of its plan with those of other organs of state and institutional role-players;

(c) regularly review and update its plan; and

(d) through appropriate mechanisms, processes and procedures established in terms of Chapter 4 of the Local Government: Municipal Systems Act, 2000 (Act No. 32 of 2000), consult the local community on the preparation or amendment of its plan.

(2) A disaster management plan for a municipal area must-

(a) form an integral part of the municipality's integrated development plan;

(b) anticipate the types of disaster that are likely to occur in the municipal area and their possible effects;

(c) place emphasis on measures that reduce the vulnerability of disaster-prone areas, communities and households;

(d) seek to develop a system of incentives that will promote disaster management in the municipality;

(e) identify the areas, communities or households at risk;

(f) take into account indigenous knowledge relating to disaster management;

(g) promote disaster management research;

(h) identify and address weaknesses in capacity to deal with possible disasters;

(i) provide for appropriate prevention and mitigation strategies;

(j) facilitate maximum emergency preparedness; and

(k) contain contingency plans and emergency procedures in the event of a disaster, providing for-

(i) the allocation of responsibilities to the various role-players and co-ordination in the carrying out of those responsibilities;

(ii) prompt disaster response and relief;

(iii) the procurement of essential goods and services;

(iv) the establishment of strategic communication links;

(v) the dissemination of information; and

(vi) other matters that may be prescribed.

(3) A district municipality and the local municipalities within the area of the district municipality must prepare their disaster management plans after consulting each other.

(4) A municipality must submit a copy of its disaster management plan, and of any amendment to the plan, to the National Centre, the disaster management centre of the relevant province, and, if it is a district municipality or a local municipality, to every municipal disaster management centre within the area of the district municipality concerned.

The roles and responsibilities of a municipal entity quoted above highlight the importance of risk reduction (pro-active thinking) and not only that of preparedness (re-active). It also emphasises that disasters are now 'everybody's business', with an emphasis on involving all role-players, other departments, such as housing and health, and organisations not historically linked to disaster management, such as library services and adult education. The Act also recognises that disasters know no boundaries and that plans and strategies should be finalised in conjunction with neighbouring municipalities and higher/lower spheres of government. Inter-sectoral and inter-departmental cooperation and planning are imperative in disaster management.

Botha and Louw (2004) developed a methodology which has been successfully used to prepare disaster management plans based on the requirements of the Act, which will be used in this study.

2.2 Disaster Risk Assessment: Methodology

2.2.1 Disaster Risk Management and the Integrated Development Plan

The Disaster Management Act (Act 57 of 2002) requires that a Disaster Management Plan of an area form an integral part of the Integrated Development Planning (IDP) process. This is also reflected in the Municipal Systems Act (Act 32 of 2002), where in Section 26 it is stated that an Integrated Development Plan must reflect the applicable Disaster Management Plans of a municipality. The National Spatial Development Perspective (promulgated in May 2006) has broadened the functionality of the IDP. It focuses on development planning within a spatial extent, not a managerial entity, irrespective of the sphere of government responsible for certain functions.

This new approach gave rise to the so-called second generation IDP, where integrated developmental planning is performed through the implementation of a systematic targeting distinct deliverables portrayed in the IDP (the Plan itself) to be addressed by municipal councils for implementation (pers comm. Rode 2007).

The IDP process has five phases namely, analysis, strategies, projects, integration, and approval. As summarised in Table 1, the analysis phase focuses on a holistic, general needs assessment and situational analysis. In the Disaster Management sector, this phase corresponds with the disaster risk assessment phase.

The strategies phase in the IDP follows the needs analysis and is aimed at developing sectoral programs and projects that is outcome orientated. This is the phase where disaster management strategies are formulised based on the disaster management framework, a strategic document, and the outcomes of the disaster risk analysis. The strategies phase includes a list of projects related to that strategy that would guide the sectoral project planning process in phase 3. During this phase the disaster management stakeholders and role-players develop disaster risk reduction (mitigation) and preparedness (response and recovery) plans.

Phase 4, the integration phase, is executed at a municipal or provincial executive level, and should consider all sectoral plans from a holistic and functional perspective. The prioritisation of projects based on disaster risk, for example, would simplify this process as the municipal/provincial budget can prove to be a constraint in the approval of projects during the next phase.

The council approves project budgets with linked targets during the approval phase, and , although not mentioned as an official phase of the IDP process, the various sectors may then proceed with implementation of their projects in the implementation phase, that would include the implementation of the disaster management plans.

Table 1: The linkages between the Disaster Management and IDP processes (derived from Rode pers comm. 2007)

	Description	IDP	DMP
PHASE 1: Analysis	Needs assessment and prioritisation Situational analysis	General /Holistic	Sector specific; Disaster Risk analysis
PHASE 2: Strategies	Component driven Capacity and capability Participation and Prioritisation	General; different activities (of formulating strategies) occur parallel to each other	As a sectoral plan (strategy) with feedback to main process
PHASE 3: Projects	Develop sectoral programs/projects and targets Outcome orientated	Sectoral plans are developed	Disaster Risk Reduction plans; Preparedness Plans
PHASE 4: Integration	Integration (holistic, functional) Prioritisation (holistic, functional) Indicators (holistic, functional) Discount output in budgets	Accommodate sectoral plans (strategies) in mainstream plan	Disaster Management Plan that is part of the IDP
PHASE 5: Approval	By Council: Budget with linked Targets (holistic and functional)	Approval of project and holistic alignment	Part of IDP process

As summarized in the previous paragraphs, the disaster risk assessment corresponds with the analysis phase in the IDP process. The steps to execute a disaster risk assessment include information collection, hazard identification, a risk profiling assessment, which includes a qualitative assessment of hazard, vulnerability and capacity to cope, and a resulting risk prioritization. The general methodology for each step is discussed in the following paragraphs.

2.2.2 Assessing disaster risk: general methodological approach

For the purpose of this study, disaster risk is defined as the possibility, or chance, of harmful consequences, or expected loss (of lives, people injured, property, livelihoods, economies activity disrupted or environment damaged) resulting from interactions between natural and human-induces hazards and vulnerable conditions (UNISDR 2002). Consensus have however not yet been reached internationally on the methodology of quantifying risk (pers comm. Thywissen 2007) The United Nations lists 14 definitions for hazard, 36 for vulnerability and 30 for risk (Thywissen 2006). In general it is agreed that risk is a function of hazard, vulnerability, resilience, capacity to cope, and exposure.

Mathematically, it is expressed as:

$$\mathbf{R} = f(\mathbf{H}, \mathbf{V}, \mathbf{CC}, \mathbf{E}, \mathbf{R}, \ldots..)$$

Where: **R = Risk**

H = Hazard

V = Vulnerability

CC = Coping capacity

E = Exposure

R = Resilience

The exact mathematical relationship between the variables is however unknown, although many agree on a basic equation where Risk = Hazard x Vulnerability (Villagrán de Leon 2006). The same author concluded that Risk = Hazard x Vulnerability x Deficiencies in Preparedness. Although recently published, this definition is similar to the basic definition of risk defined by Botha and Louw (2004) where

Risk = Hazard x Vulnerability / Manageability.

Manageability is also generally referred to as 'capacity to cope'. One should exercise care when quantifying risk in any manner, due to the fact that a certain variable may be over- or under-emphasized. Thywissen (pers comm. 2007) however confirmed that it may in some cases be used for comparative risk scores as the over- or under-emphasis would be constant.

2.2.2.1 Step 1: Information collection

Information regarding all existing hazards and prevailing conditions in the area needs to be collected. ***Seasonal climate forecasts*** from the South African Weather Services (SAWS) web site (http://www.weathersa.co.za/) and the Global Forecasting Centre for Southern Africa (GFCSA) web site (http://www.gfcsa.net) are, amongst others invaluable tools for disaster risk planning. Information collection should however not be limited to climate-related information and a thorough literature search on existing and threatening hazards should be conducted simultaneously. Information is also collected on demography, landcover, landuse, infrastructure and topography.

2.2.2.2 Step 2: Hazard Assessment

The purpose of the hazard assessment is to assess current and future hazards. The assessment involves the listing of hazards that occurred in that area in the past, as well as list the incidents and impact. Future hazards are also researched during this step. Using questionnaires, the assessment is ideally initiated in a workshop environment, in consultation with disaster management role-players in the area. (Botha and Louw 2004)

2.2.2.3 Step 3: Risk Profiling Assessment

The risk profiling assessment is conducted spatially and qualitatively and uses the information collected in the information collection and hazard identification phases to complete the following steps:

Primary Impact Mapping: The primary areas of incidence for each identified hazard should be mapped. This is followed by a vulnerability analysis to determine the impacts of the identified hazard on society, the environment, the economy and critical facilities.

Societal Vulnerability Analysis: The focus of this step is to identify those areas where individual resources are minimal.

Environmental Vulnerability Analysis: The purpose of this analysis is to identify locations where there are potential for secondary environmental impacts from natural hazards and to target vulnerable locations for risk reduction activities.

Economic Vulnerability Analysis: Economic vulnerabilities to hazard impacts is be identified.

Critical Facilities Vulnerability Analysis: This analysis focuses on determining the vulnerability of key individual facilities or resources within the area.

2.2.2.4 Step 4: Risk Prioritisation

The South African National Disaster Management Framework (RSA 2005) gives certain guidelines on the execution of a disaster risk assessment, and specifically instructs that the level of risk associated with a hazard is estimated to determine whether it is a priority or not (section 2.1.3.2). When several hazards (threats) are present in an area, a further prioritisation is required. This process, called risk evaluation in the national framework, is necessary because it is unlikely that budgets and resources are available to address all threats at the same time. The prioritisation of risks therefore assists in the allocation of budgets across the various sectors in a municipality of province. This methodology (Botha and Louw 2004) uses the terminology 'risk prioritisation' to comply with these stipulations in the national framework, and is based on methodologies used by the United States Federal Emergency Management Agency (FEMA), the United Nations Disaster Management Training Programme (UNDMTP) and the Cranfield Disaster Management Centre.

The risks of an area or community are quantified to enable prioritisation of risk reduction and preparedness strategies and plans. The process uses a simple model that quantifies total risk, risk manageability and results in a relative risk priority list. Each of these steps is discussed below. Firstly, the *risks to an area* are quantified using a simple model to determine *total risk.* This concept is illustrated in Figure 3. Three parameters are rated, namely exposure, frequency and severity. Exposure is measured to partly quantify vulnerability, and frequency to derive probability. Vulnerability is however also assessed spatially during the risk assessment process. Probability (the frequency of the event) and severity (the intensity of the event) are indicators of the hazard. In combination, they give an indication of total risk.

Exposure*:* The temporal exposure of a community or an area to a particular hazard is assessed and classified in three categories, namely:

> *Continuous:* a continuous exposure, such as living in a malaria endemic area (rating = 3).
>
> *Occasional*: an occasional exposure to a hazard, such as living below the one in fifty year flood (rating = 2).
>
> *Seldom:* a community or area is seldom exposed to a particular hazard (rating = 1).

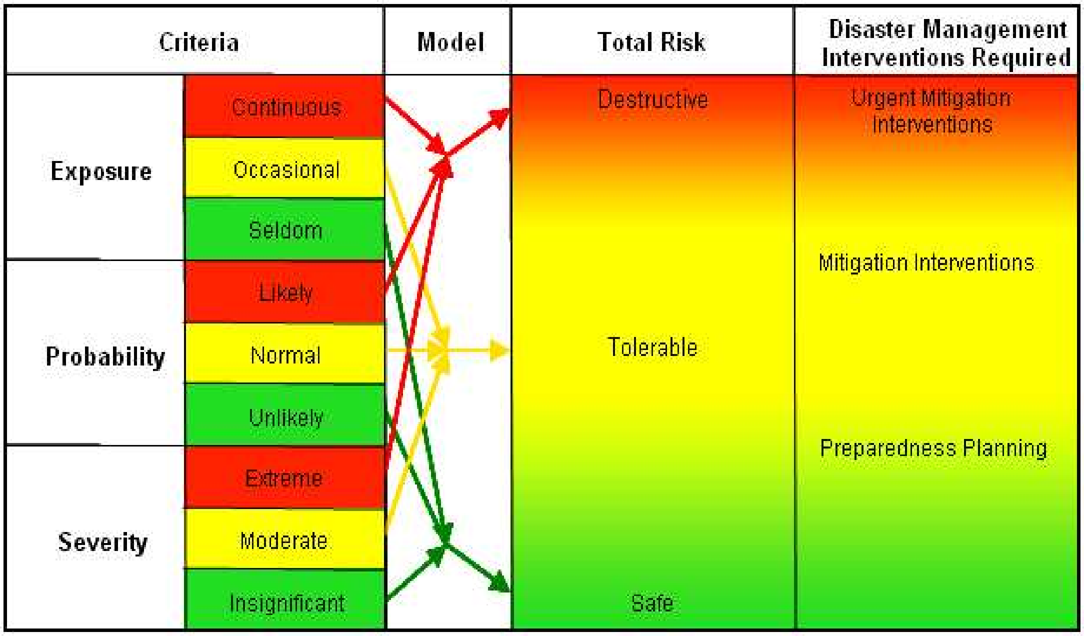

Figure 3: Model illustrating the evaluation of the total risk of an area

***Probability*:** The probability of a hazard occurring is assessed and classified in three categories, namely:

Likely: hazards in this category will have a very high probability of occurrence (rating = 3).

Normal: hazards in this category will have a 50% probability of occurrence (rating = 2).

Unlikely: hazards in this category will have a very low probability of occurrence (rating = 1).

Severity: The severity of the hazard, should it occur, is assessed and categorised as extreme, moderate or insignificant:

Extreme: hazards in this category will have extreme consequences to a community (rating = 3).

Moderate: hazards in this category will have moderate consequences to a community (rating = 2).

Insignificant: hazards in this category will have insignificant consequences to a community (rating = 1).

The total risk score for a specific hazard is then calculated by multiplying the allocated ratings for exposure, probability and severity. This score may vary between a maximum value of 27 (27 = 3 X 3 X 3) indicating maximum total risk and a minimum value of 1 (1 = 1 X 1 X 1) for a low risk:

Total risk score ≥ 18: Should the risk score of a particular hazard event impacting on a community be higher or equal to 18, that community is exposed to a potentially destructive risk, with a high probability of occurrence.

4 < Total risk score < 18: If the risk score of a particular hazard event impacting on a community is between 4 and 18, the risks to which the community are exposed can be tolerated.

Total risk score ≤ 4: Risk scores of a particular hazard event impacting on a community lower than or equal to 4 translate to a relatively small risk for a community.

The total risk analysis is followed by a risk manageability analysis focussing on determining the degree to which a community can intervene and manage (or cope with) the identified hazard and total risks. The analysis should be completed in a workshop environment, involving as many of the role-players as possible. The parameters listed below are assessed. For each hazard a score for manageability of either 1, 2 or 3 is allocated where 1 = poor , 2 = modest and 3 = good:

Awareness: The overall awareness of people living in a potential impact area of a specific hazard

Legal Framework: The existence of a legal framework and strategies governing the specific hazard, or a legal framework enabling effective disaster management, such as a disaster management framework.

Early Warning Systems: Existing and efficient early warning systems for a specific hazard in place.

Government Response: The speed and effectiveness of government response to a hazard incident.

Government Resources: The availability of government resources to deal with a specific hazard. Examples include trained personnel, budget and fire engines.

Existing Risk Reduction Measures: The existence of effective risk reduction measures to reduce the risk of a hazard incident.

Public Participation Measures: An informed public about the impacts of a hazard, trained to react and involvement in either risk reduction or preparedness processes through public participation.

Municipal Management Capabilities: Consistent, reliable and informed municipal management to take responsible decisions regarding Disaster Management for a specific hazard.

A simple arithmetic model was utilised to quantify the degree to which the community can intervene and manage the negative consequences of a hazard event. The ability to cope with or manage a specific hazard is quantified by the sum of the scores for each of these parameters.

The classes of the Risk Manageability Score used in the model are allocated as follows:

> **Risk Manageability Score ≥ 18:** The community has a very high level of manageability and it is unlikely that the hazard event will impact negatively on the community.
>
> **8 < Risk Manageability Score < 18**: The community has a modest level of manageability and it is likely that the hazard event will impact negatively on the community.
>
> **Risk Manageability Score ≤ 8:** The community displays a poor level of manageability and it is highly likely that the hazard event will impact negatively on the community.

Using the results of the total risk analysis and the risk manageability analysis, the relative risk score is calculated using the formula below:

Relative Risk Priority Score =	**Total Risk Score / Total Risk Manageability Score**

The results are categorised as follows:

> **Relative Risk Priority ≥ 2**: a destructive risk with a high probability of occurrence, for which the community is unprepared. This indicates urgent risk reduction planning for the rated hazards.
>
> **1 < Relative Risk Priority < 2:** a tolerable risk and a community that is moderately prepared for the hazard event. A combination of risk reduction interventions and preparedness planning for these hazards are recommended.
>
> **Relative Risk Priority ≤ 1**: Very little risk for a largely prepared community, which requires only preparedness plans.

2.2.2.5 Step 5: Inclusion in Sectoral Plans

Once the mapping of the risk profiles for communities in the district have been completed, the spatial information is provided to the municipality with the recommendation that is should be included in the Spatial Development Framework (SDF), the Local Economic Development Plan and the Medium Term Expenditure Framework. This enables inter-sectoral and inter-department planning practices.

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C H A P T E R 3

The Climate Change phenomenon

This chapter explains and summarises the concepts of climate and discusses the predictions globally and locally.

3.1 Climate change – the scientific basis

This section gives a brief overview of the scientific basis as summarised by the Intergovernmental Panel on Climate Change in their 2001 synthesis report (IPCC 2001, 2007). Unless indicated otherwise, all information summarised are from this source. The IPCC is an international body which was jointly established in 1998 by the World Meteorological Organisation and the United Nations Environment Programme. Its present terms of reference are to:

- Assess available information on the science, the impacts and the economics of – and the options for mitigating and/or adapting to – climate change,
- Provide, on request, scientific/technical/socio-economic advice to the Conference of Parties to the United Nations Framework Convention on Climate Change." (IPCC 2001)

Since its establishment, the IPCC has produced a series of Assessment Reports, Special Reports, Technical Reports, and methodologies, which have become standard works of reference, widely used by policymakers, scientists and other experts.

The predictions made in the IPCC reports are internationally recognised as the benchmark and is certainly regarded as such by leading researchers in South Africa. It is not the intention of this study to question the methodologies and predictions of this body of leading scientists. Many uncertainties do however exist, and will be discussed under the appropriate sections.

The IPCC defines climate as the average weather over periods of longer than a month. Variations in climate are normal. The earth's climate has never been stable over extended time periods. These variations can be ascribed to variability of energy emitted from the sun, changes in distance between the earth and the sun and the presence of volcanic pollution in the upper atmosphere

(Appleton 2003). Fluctuations are also produced by internal variations through feedback processes that connect various components of the climate system.

Variability is defined as the range of values that the climate at a particular location can take over time. It is an inherent feature of the natural climatic system. (IPCC 2001) The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition *to natural climate variability observed over comparable time periods* (Appleton 2003)

Paleoclimatic records obtained from Antarctic ice cores for periods as far back as 4000 years show natural variability in temperature, carbon dioxide (CO_2) and methane (CH_4) levels. The latter two are considered the most important greenhouse gases in terms of radiative forcing. The composition of the atmosphere has, however, through human activities, been progressively altered since the expansion of agriculture and the industrial revolution. Human activities have increased the emissions of greenhouse gases and aerosols, which, according to recent observations, have given rise to a projection of a warmer world (IPCC 2007).

Most greenhouse gases reached their highest recorded levels in the 1990's. Greenhouse gases (CO_2, CH_4, ozone and oxides of nitrogen) retain heat and help to maintain an increased temperature on earth. Burning of fossil fuels and changes in land-use through deforestation are responsible for nearly 75% of the increase in CO_2 (levels increased from 228 parts per million by volume (pomp) to 369 pomp since 1860). An increase in the CH_4 level could be identified emanating mainly from emissions from energy use, livestock, agriculture and landfills. Fossil fuel combustion is also directly responsible for increased concentration in tropospheric ozone (O_3), the third most important greenhouse gas. The indicators of human influence on the atmosphere during the industrial era are illustrated in Figure 4. The global average near-surface temperature has increased about 0.6˚C since 1900. The rate and duration of temperature increase during the 1900's have been significantly greater than that of the previous 900 years (Figure 5). 1998 was the warmest year of the previous millennium on record, and the 1990's the warmest decade (Appleton 2003). The figure shows that the earth's surface temperature has increased by approximately 0.6˚C over the record of direct temperature measurements (1860-2000) (IPCC 2001).

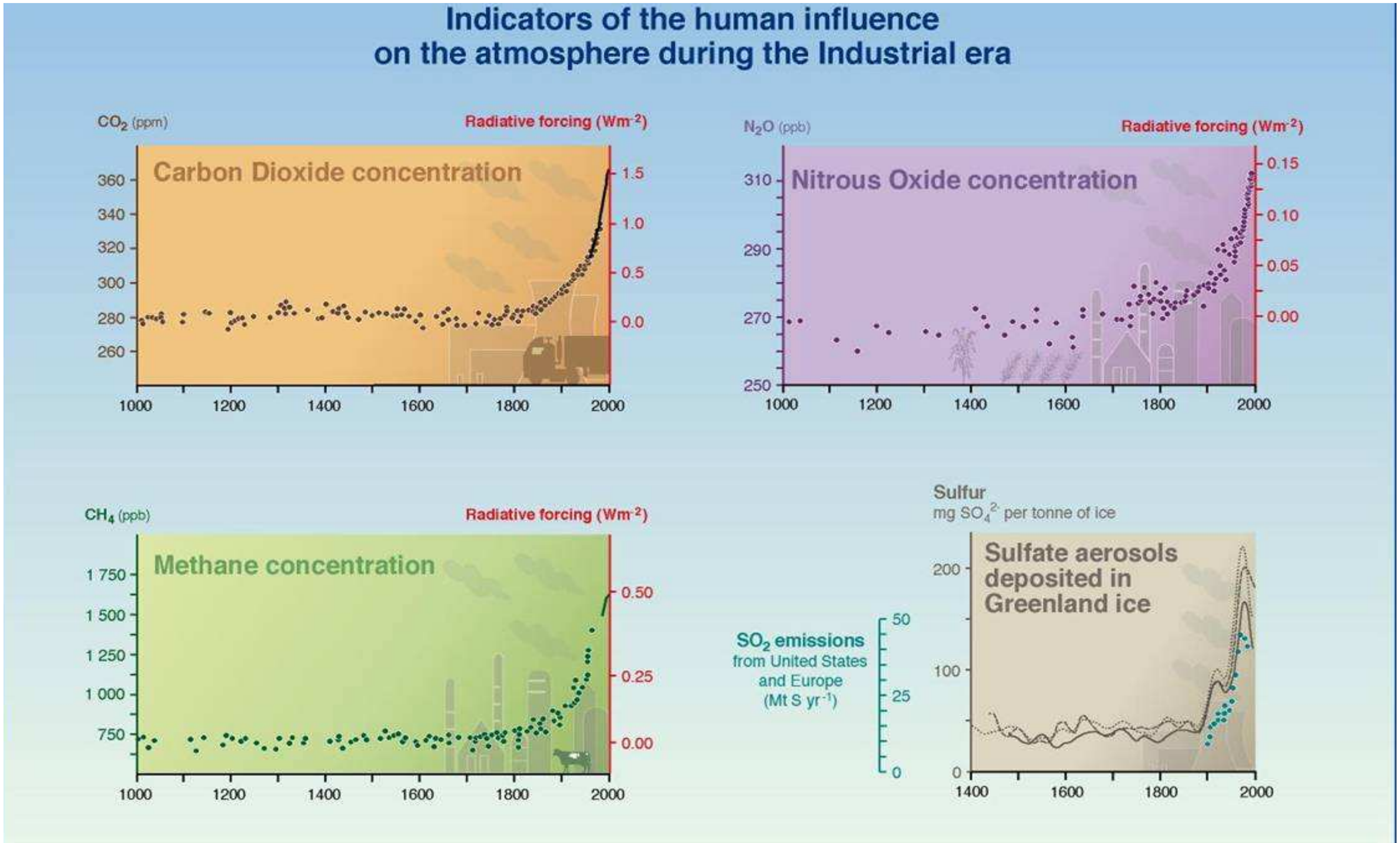

Figure 4: Records of past changes in atmospheric composition over the last millennium demonstrate the rapid rise in greenhouse gases and sulphate aerosols that is attributed primarily to industrial growth since 1750 (IPCC 2001)

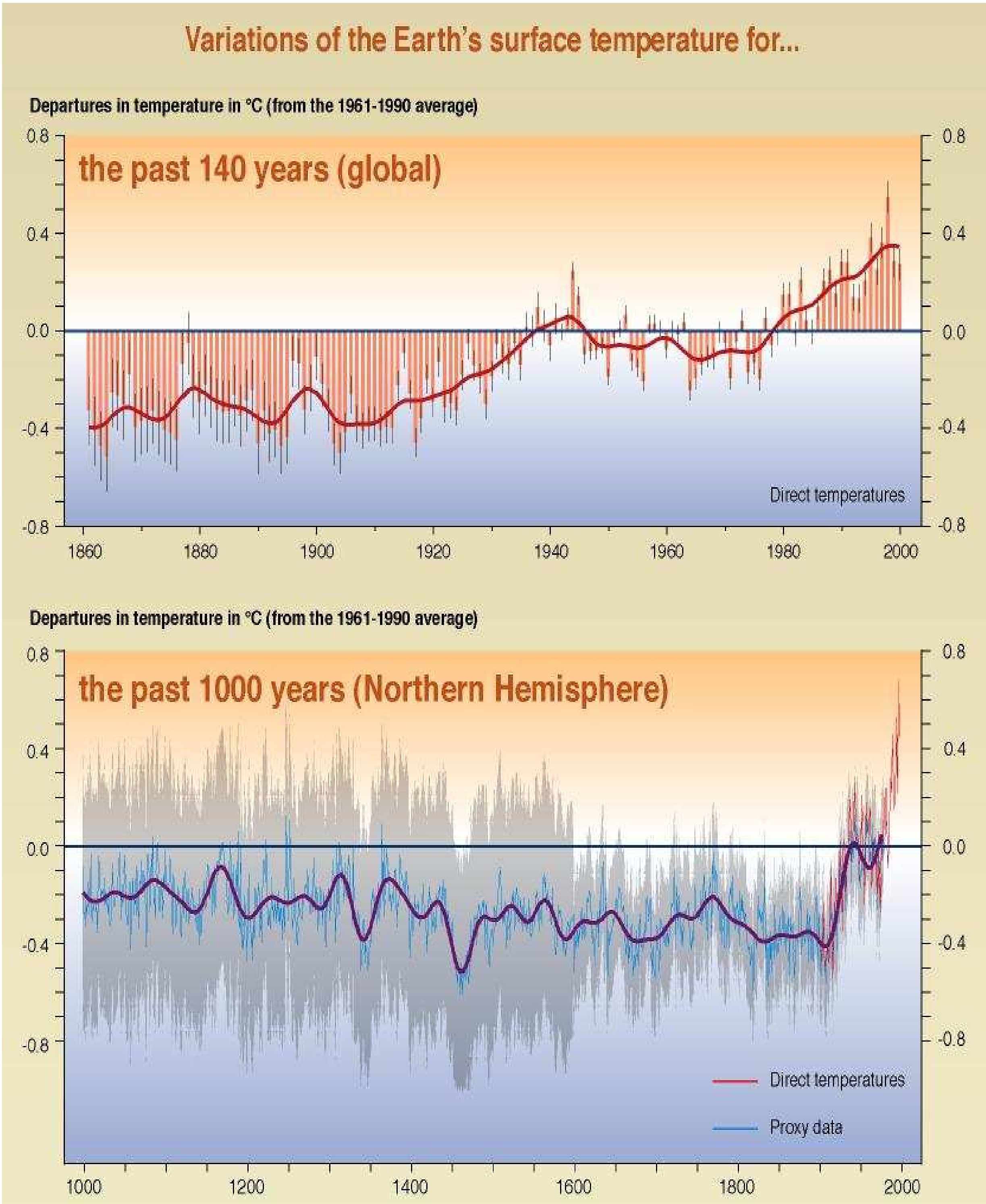

Figure 5: Variations of the earth's temperature (IPCC 2001)

The IPCC also stated that:

- the sea-level has risen (on average) 1 to 2 mm per year
- temperature in the lowest 8 km of the atmosphere have increased during the past 40 years
- ocean heat content has increased
- surface precipitation (rain, snow, hail) continue to show an increase of 0.5 % to 1% per decade over much of the middle and high latitudes of the Northern Hemisphere
- more pronounced increases in heavy and extreme precipitation events also occurred.

For the purpose of this study (as in IPCC reports), the UNFCCC approach is adopted that restricts the use of the term climate change to projected future conditions of climate under various greenhouse gas emission scenarios.

3.2 Scenarios and modelling

As discussed in the previous section, climate changes occur as a result of both internal variability and external forces (human and natural). The increasing amounts of aerosols and greenhouse gases have been shown to impact on the climate system in several ways. These external factors are however not static. Future emissions can be influenced by fluctuating factors such as socio-economic development, technological development and population, and are thus highly unpredictable. Scenarios have been developed by the IPCC to describe these uncertainties by giving alternative images of how the future might look. It is an appropriate tool with which to analyse the different driving forces and its influence on emissions. The IPCC (2001) defines a scenario as “a plausible future outcome that has no further degree of probability attached”. The IPCC based their climate projections on emission scenarios as contained in the in the IPCC Special Report on Emission Scenarios (SRES).

The so-called SRES consist of 6 scenario groups based on narrative storylines which span a wide range of driving forces encompassed in four combinations of demographic change, social and economic development and broad technological development (A1B, A2, B1, B2) A further two scenario groups explore alternative energy technology developments (A1F1, A1T). The IPCC used these emissions scenarios to model future precipitation, temperature and sea levels. Computing limitations allowed only the modelling of the A2 and B2 emission scenarios. Climate change scenarios produced by these general circulation models (GCM's) are on a global scale with resolutions in the order of hundreds of kilometres. This resolution is not suitable for regional climate modelling (Hewitson et al 2005, Hewitson 1997, 1999, 2001). For more accurate regional and local scale modelling, a process called 'downscaling' is used. This methodology will be discussed in a following section. In the next section the general projected changes for the 21st century are focused on.

3.3 Projected changes and their consequences

3.3.1 General

All emission scenarios show increased levels of carbon dioxide concentrations (75 to 350% above the pre-industrial levels). These projections are illustrated in Figure 6. Globally averaged water vapour, evaporation and averaged annual precipitation are projected to increase. All the SRES scenarios indicate a rise of between 0.09 and 0.88 m during the next century. There are, however, substantial differences in projected values regionally. Although the averaged annual precipitation is projected to increase in some regions, notably Southern Africa, a decrease in winter rainfall is predicted. Confidence in the regional predictions of sea level rise is similarly low due to variable data. Snow cover, permafrost and sea-ice extent are projected to decrease further in the Northern hemisphere, while the Antarctic ice sheet is likely to gain mass due to increased precipitation.

3.3.2 Annual changes in physical, biological and social systems

The impacts of climate change may not only be adverse, but may also result in beneficial environmental and socio-economic effects. It is, however, likely that adverse effects will dominate with larger changes and rates of change. Greater accumulative emissions of greenhouse gases will therefore result in more severe impacts.

Threats to human health are projected to increase overall, particularly in lower-income populations in tropical and sub-tropical countries. This can be either directly through, for example, reduced cold spells with a resulting increase in heat stress, loss of life in floods and storms, or indirectly through changes in the ranges of disease vectors, water-borne pathogens, water and air quality, food availability, population displacement and economic disruption. The predominant effect is projected to be adverse, but some impacts, for example, decreased cold stress and disease transmission, may be beneficial.

Biodiversity in ecosystems is projected to be affected, with an increased risk of extinction of some vulnerable species. The stresses caused by climate change threaten not only damage, but result is a complete loss of unique ecosystems and the extinction of endangered species. Examples of these stresses include: drought, fire, pest infestation, invasion of detrimental exotic species, storms and coral bleaching aggravating existing stresses such as land degradation. The effects of climate change on the productivity of ecosystems vary, since net primary productivity would be increased by increasing CO_2 concentrations. This may be either augmented or reduced by climate change, depending on, inter alia, the vegetation type. Climate change may also interfere with the net uptake of carbon by the terrestrial ecosystems, which currently acts as a carbon sink.

The effects of climate change on agriculture vary regionally. In mid-latitudes, positive responses of yield on minimal increases in temperature and CO_2 are expected. For larger increases, a reduction in yield is projected. A decrease in yield under even minimal changes in temperature is, however, predicted for tropical areas. The effects would be even more adverse when they coincide with a large decrease in rainfall in subtropical and tropical dry land systems. The effects of CO_2 fertilisation is taken into account in the above predictions, but not the impacts of pests, diseases, degradation of soil and water resources or climate extremes. Figure 7 illustrates the ranges of percentage changes in crop yield across the globe.

Climate change may alleviate water shortages in some regions, but are projected to adversely affect water supplies in already water-scarce areas, as it is projected to reduce stream flow and groundwater recharge in many parts of the world.

Projected changes in water resources vary among the different scenarios due to the differences in rainfall projections and evaporation. Stream flow changes indicates a supply reduction of 10% or more by the year 2050 affecting up to a few billion people (corresponding to a 1% annual increase in CO_2).

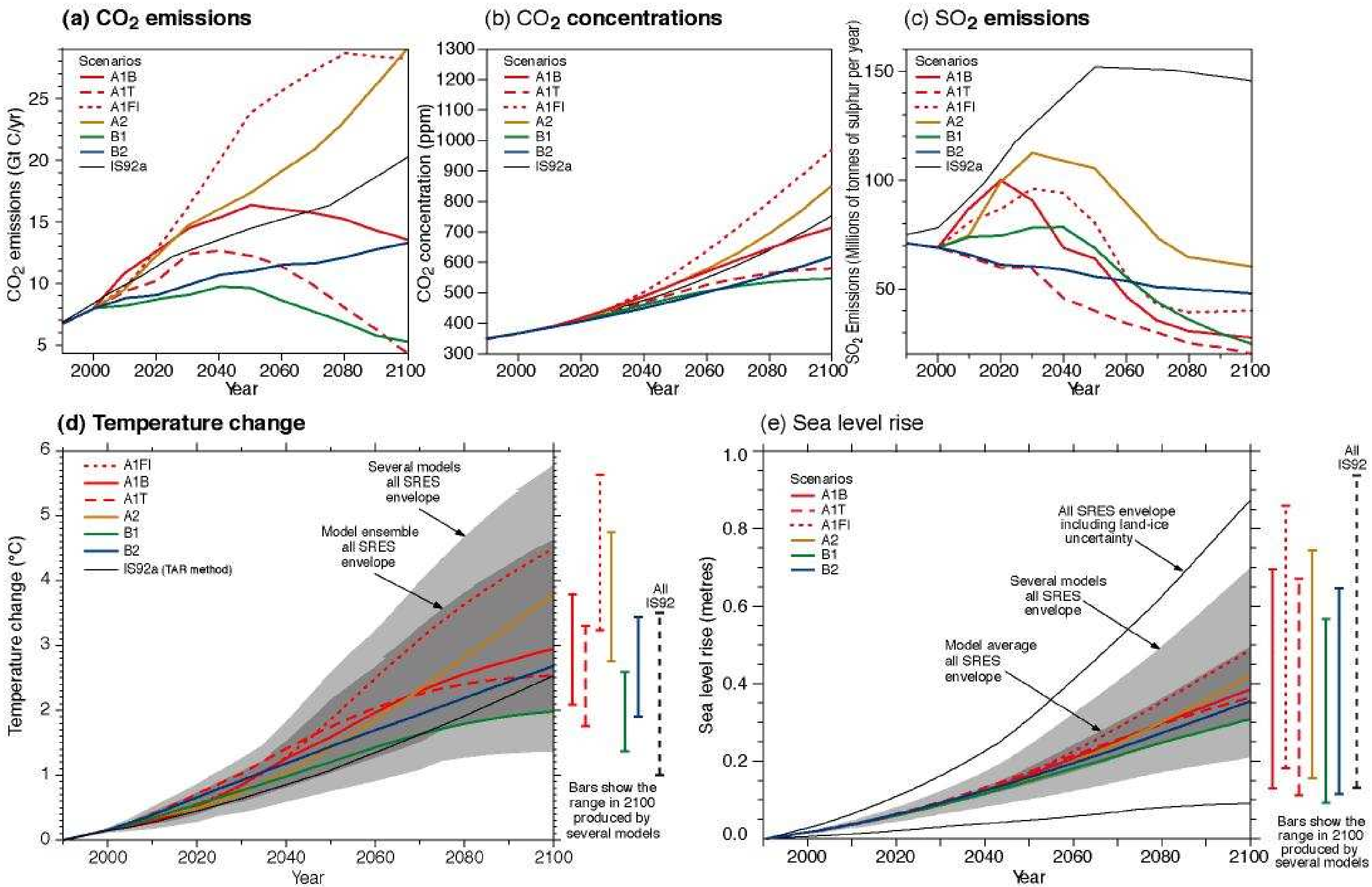

Figure 6: The global climate of the 21st century (IPCC 2001)

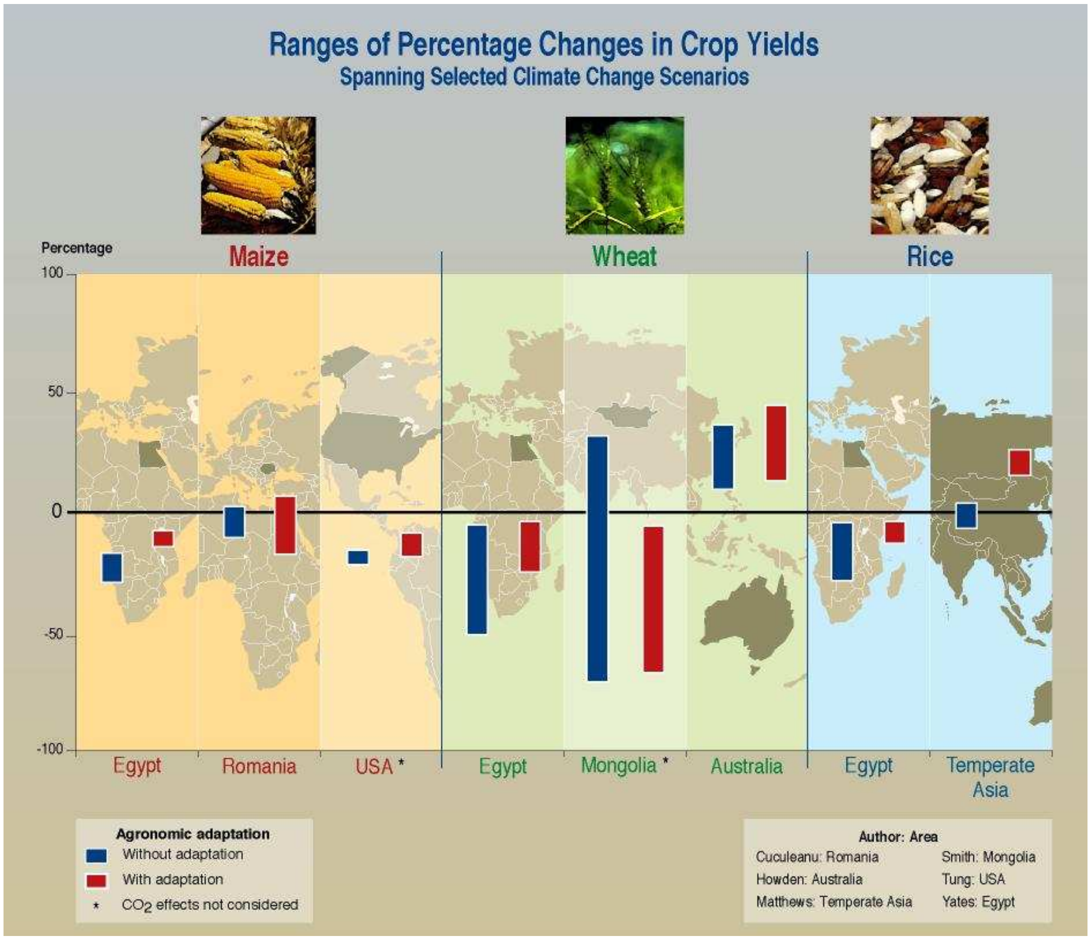

Figure 7: The ranges of percentage changes in crop yield across the globe

Freshwater quality is projected to be negatively influenced in general. Water scarcity, water quality and flood frequency and intensity all exacerbate challenges in already poorly managed water systems. Human settlements in deltas, low-lying coastal areas and on small islands will face an increased risk of flooding and erosion, displacement of populations, loss of infrastructure and loss of resources such as fish, coral reefs, beaches and fresh water. Communities in southern and south-east Asia are at particular risk.

3.3.3 Changes in frequency and magnitude of climatic fluctuations

Models predict that daily, seasonal, inter-annual and decadal variability will change. Diurnal temperature ranges may decrease in many areas, with night-time lows increasing more than daytime highs. A number of models project a general decrease of daily variability of surface air temperature in winter and an increase during summer for the northern hemisphere land areas.

A small increase in the amplitude for El Niño events is projected, which will result in a mean eastward shift in precipitation. Global warming is also said to be likely to increase the risks of droughts and floods that normally occur during El Niño events, even with little or no change in El Niño strength. No changes in frequency or structure for the North Atlantic Oscillation (NAO) are projected with certainty. The El Niño and NAO do however play a major role in global climate. Variability in changes in the variance and frequency of extreme events may be the result of changes in means as well as changes of specific circulation patterns.

Figure 8 shows the effects on temperature when either the mean or the variance increases or both increase, leading to more hot weather with fewer frost days and cool waves. These predicted changes will result in crop and livestock losses, increased energy consumption (cooling and heating), increased human morbidity and heat related mortality. The projected return period for extreme precipitation events shows a decrease, resulting in, inter alia, more frequent floods, landslides, loss of life, health impacts, soil erosion and agricultural losses.

High resolution modelling projects an increase of 5% to 10% in peak wind intensity and a 20% to 30% increase in precipitation of tropical cyclones. Changes in frequency of tropical cyclones have not been projected consistently. Insufficient information on changes in smaller scale phenomena, i.e. thunderstorms, tornadoes, hail and lightning exist, as they are not yet simulated in models.

Large-scale, high-impact, non-linear and potentially abrupt changes in physical and biological systems could be set in motion by an increase in greenhouse gas concentrations over the next few hundred years. This is attributed to the complex, non-linear interactions in a climate system, giving rise to thresholds. It includes phenomena such as large increases in greenhouse gas emissions from terrestrial ecosystems, a collapse of the thermohaline circulation and disintegration of the Antarctic and the Greenland ice sheets. A recent report by GEUS (Geological Survey of Denmark) indicated that the Sermilik glacier in Southern Greenland shrunk 150 m in the last 15 years (Shukman 2007). It is unlikely that these abrupt changes will take place during the 21st century. Greenhouse gas forcing could however set the processes in motion. The greater the magnitude and rate of these changes, the greater the risk of adverse impacts. In ecosystems, it could affect their biodiversity, productivity and function.

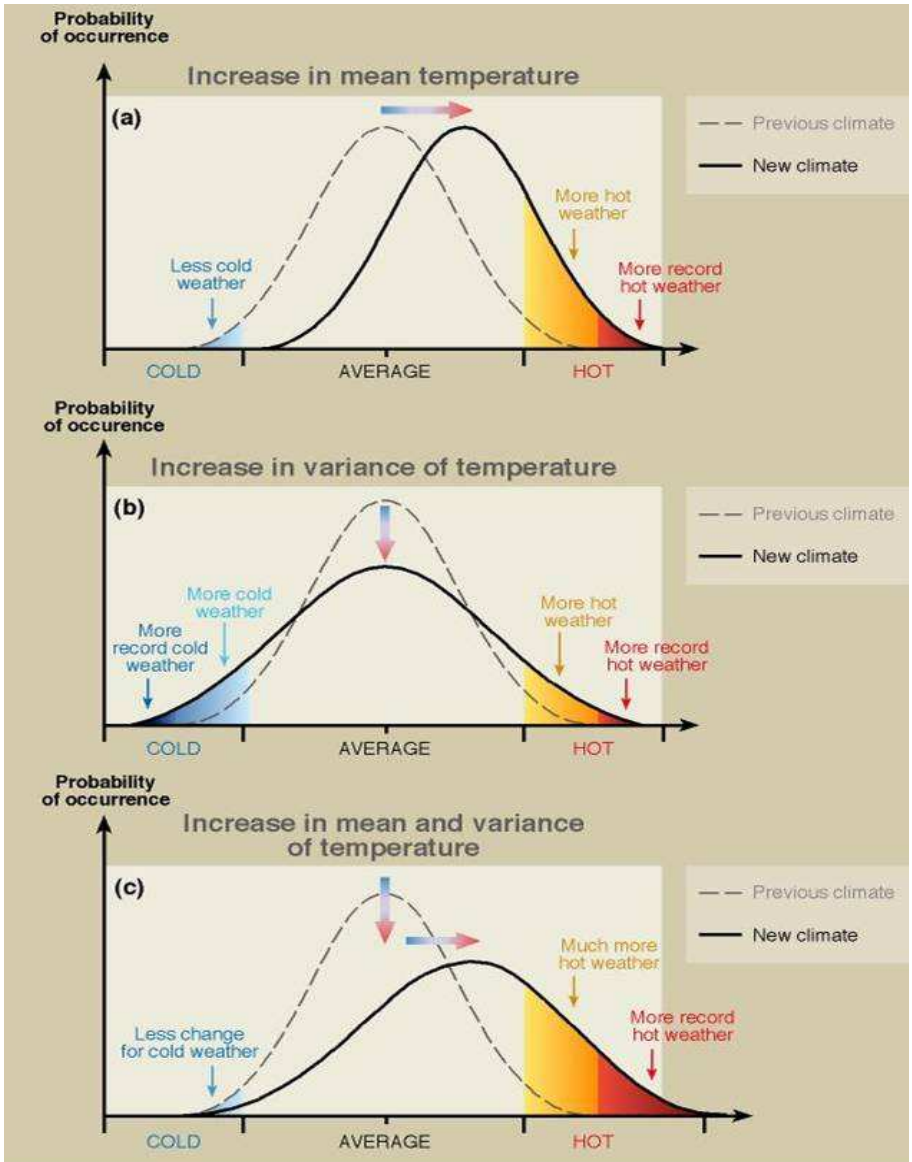

Figure 8: The effect of an increase in mean temperature on the frequency of extreme events (IPCC 2001)

A change of as little as 1˚C for example, can lead to corals ejecting their algae (coral bleaching) leading to their eventual death with a resultant loss in biodiversity. Key development stages in some crops can be affected by temperature increases beyond certain thresholds (thresholds vary by crop and variety). This can result in severe crop losses if temperatures exceed critical limits even for shorter periods.

Large-scale vegetation changes, for example a change in land cover, affect regional climate through modification in energy, water and gas fluxes, affecting atmospheric composition. At a local/regional scale in areas without surface water, evaporation and albedo changes can affect the local hydrological cycle. A reduction in vegetative cover could, for example, lead to reduced precipitation and change the frequency and severity of droughts. Rapid increases in atmospheric methane (CH_4) appear exceptionally unlikely.

3.3.4 Inertia and time-scales of change

Inertia is defined as a delay, slowness or resistance in the response of climate, biological or human systems to factors that alter their rate of change, including continuation of change in the system after the cause of that change has been removed (IPCC 2001). Inertia is an inherent characteristic of the interacting climate, ecological and socio-economic systems. Impacts of climate change may be slow to manifest, but could become irreversible if certain thresholds are crossed. Inertia and varying time-scales associated with important processes in the interacting climate, ecological and socio-economic systems and potential irreversibility are discussed below.

The combined effect of the various inertias mentioned will result in a stabilisation of climate systems only after considerable time after a reduction of greenhouse gases. The main sources of physical inertia for the climate system for time scales up to 1000 years are the oceans and the cryosphere (ice caps, ice sheets, glaciers and permafrost). As a consequence, sea-level rises due to anthropogenic forcing will continue, possible for centuries, after the stabilisation of greenhouse gas concentrations in the atmosphere, surface air temperatures also continue to rise for the next hundred years or more. This is illustrated in Figure 9.

Carbon cycle models indicate that atmospheric CO_2 would continue to increase, even if emissions were held at present levels. Stabilisation of atmospheric CO_2 levels therefore would require an ultimate reduction of global CO_2 emissions. Stabilisation at 450 ppm would, for example, require that CO_2 emissions drop below the 1990 level. This is the result of the slow transport of carbon on the ocean's surface and deep waters, which affects the rate of CO_2 uptake. It is estimated that there is sufficient CO_2 uptake capacity in the ocean to incorporate up to 80% of future CO_2 emissions This will however take several centuries. A delay between this uptake and carbon release will manifest as a temporary net carbon uptake and, according to several models, ought to peak within the 21st century.

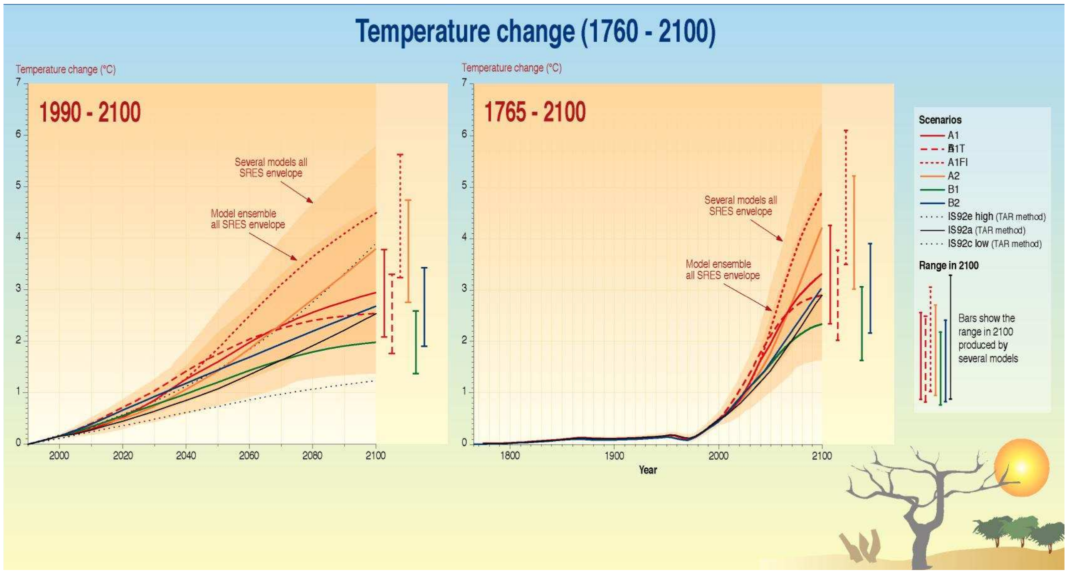

Figure 9: The continued increase in temperature over the next 100 years for all scenarios (IPCC 2001)

Response times within the ecological system when subjected to rapid climate change are likely to be severely altered. The resulting loss of capacity to supply, for example, food, timber and maintain biodiversity, may not be apparent immediately.

Human adaptation to extremes and inter-annual variability in climate has proven more difficult than adaptation to long-term mean climate conditions. The magnitude and rate of changes will challenge human societies' adaptation more than it did at any time during the past five millennia. Inertia in decision-making seems to exist in the area of adaptation and mitigation. Typically a delay of even decades between recognising a need to respond and implementing mitigation strategies can occur. Effective adaptation to change can be delayed if these changes, such as frequent droughts, are perceived to be part of natural climate variability. The opposite is also true, resulting in mal-adaptation. Social and economic time scales are sensitive to many forces and could therefore be defeated by choices and policies. It is also probable that in situations where pressure to change is small, large inertia will be experienced.

Climate, ecological and social system changes can be either effectively irreversible over human lifetimes, or intrinsically irreversible. Effective irreversibility is defined as processes that, over time (periods of centuries to millennia), have the potential to return to their pre-disturbance state Intrinsic irreversibility however results from crossing a threshold beyond which the system is no longer capable of returning spontaneously to the pre-disturbance state. Climate change and habitat loss can, for example, cause the extinction of species. The location of these thresholds (the resistance to change of the system) can be affected by the rate which it is approached. Threshold crossings are therefore more likely to occur with higher rates of warming combined with other stresses, and may not be apparent until it is reached in systems that are not fully understood.

In summary, inertia and uncertainty in the climate, as well as in ecological and socio-economic systems necessitate adaptation and mitigation strategies to avoid dangerous levels of interference in the climate system. Atmospheric CO_2 levels, temperature or sea levels may be affected by the inertia of the climate system (causing climate change to continue in spite of implemented mitigation actions), uncertainty regarding the location of thresholds and probable system behaviour and the time lags between adaptation of mitigation procedures and the results thereof. Anticipatory adaptation and mitigation are therefore essential. Delayed action may exclude certain adaptation and mitigation options.

3.3.5 Addressing climate change

As discussed in the previous section, it is clear that adaptation is a necessity. The cost of adaptation can be reduced by anticipation, analysis and planning. Adaptation, both anticipatory and reactive, varying according to location and sector, can potentially reduce impacts of climate change, enhance beneficial impacts and produce many immediate ancillary benefits. All damages, however, will not be prevented. The potential for adaptation is more limited for developing countries, which are projected to be more adversely affected. Adaptation can be reduced significantly when policies and measures also contribute to other goals of sustainable development. A number of formal strategic frameworks and interventions have been established at international level. These include the United Nations Framework Convention on Climate Change, the United Nations Convention to Combat Desertification in Countries Experiencing Serious Droughts, the Ramsar Convention and the Montreal Protocol. Details of each are given in Annexure D.

Mitigation seems to primarily benefit economies through avoiding costs. Comprehensive, quantitative estimates of global primary benefits of mitigation do not exist and costs and benefits vary widely across sectors. In some sectors, such as coal, oil, gas and some energy-intensive industries based on energy produced from fossil fuels, the benefits may be adverse. Substantial technological and other opportunities exist for lowering mitigation costs. Technological options include the reduction of global emissions of 1.9 to 2.6 Gt C_{eq} yr^{-1} by 2010 and 3.6 to 5.0 Gt C_{eq} yr^{-1} by 2050. Half of these reductions may be achieved with one component of their economic cost (net capital, operating and maintenance cost) with direct benefits.

The location of emissions, the local climate, the population density, composition and health impact on the ancillary benefits of mitigation, which may be comparable to the costs of mitigating policies. Instruments such as taxes or auctioned permits can also reduce the cost of achieving greenhouse gas reductions by providing revenues to the government. It is even possible that the economic benefits may exceed the cost of mitigation under some circumstances.

Models show that mitigation cost can also be reduced by emissions trading based on Kyoto targets by the Annex B group of the countries. The Kyoto protocol was adapted at the third session of the Conference of Parties to the UNFCCC (United Nations Framework Convention on Climate Change) in 1997 in Kyoto, Japan. It contains additionally (to those included in UNFCCC) legally binding documents in which countries in Annex B of the protocol agreed to reduce their anthropogenic greenhouse gas emissions (CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride) by at least 5% below 1990 levels in the commitment period 2008 to 2012. Other countries, such as Annex 10ECD, Annex I economies in transition, oil exporting, non-Annex I countries may all be affected in different ways. These predictions are however based on assumptions base on key uncertainties. The 2006 emissions data (updated annually) shows that industrialised countries will have to intensify their efforts to reduce greenhouse gas emissions. Emissions were 3.3% lower in 2004 than the 1990 level. Mitigation actions for reducing carbon emissions are summarised per sector Table 2. The sectors are listed form top to bottom where cost-effective reductions can be achieved (IPCC 2001). The transport remains a challenge, but the challenge is understood and the Kyoto protocol is guiding the Annex 1 parties in identifying and implementing policy options (UNFCCC 2007). The Third Assessment Report and other studies have contributed significantly to the understanding of climate change and the human response to it. Future work is however required in some important areas, as listed by the IPCC (IPCC 2001). These include the:

- detection and attribution of climate change
- understanding and prediction of regional changes and climate extremes
- quantification of climate change impacts at the global, regional and local levels

- analysis of adaptation and mitigation activities
- integration of all aspects of the climate change issue into strategies for sustainable development
- comprehensive and integrated investigations to support the judgement as to what constitutes dangerous anthropogenic interference with the climate system.

Table 2: Mitigation actions for reducing carbon emissions (summarised from IPCC 2007)

Sector	Current mitigation technologies	Future potential for mitigation
Building	Efficient lighting; more efficient electrical appliances; better insulation and ventilation; solar-powered heating/cooling; alternative refrigeration fluids; recovery and recycling of fluorinated gases	Integrated soar voltaic electricity; smart metering, intelligent controls
Industry	More efficient electrical equipment, heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions	Advanced energy efficiency; CCS* for cement-, ammonia- and iron manufacture; inert electrodes for aluminium manufacture
Energy supply	Improved supply and distribution efficiency; combined heat-and power systems; switching from coal to gas; nuclear power; renewable heat and power; CCS techniques	CCS for gas; biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable including tidal and wave energy
Agriculture	Improved land management; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques/livestock and manure management to reduce methane emissions; improved nitrogen fertiliser application, replace fossil-fuel use with dedicated energy crops	Improvement of crop yields
Forestry	Forest management; new forestation; reforestation and reduced forestation; harvested-wood product management; use of forestry products for bio-energy to replace fossil-fuels	Tree-species improvement to increase biomass productivity and carbon sequestration; improved remote-sensing technologies for analysis of vegetation/soil-carbon sequestration potential and mapping land-use change
Transport	More fuel-efficient, hybrid vehicles; cleaner diesel; bio-fuels; shift from road- to rail and public transport systems; more cycling/walking; land-use and transport planning	Second-generation bio-fuels; more efficient aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries.

* carbon dioxide capture and storage

Since the IPCC Third Assessment report (IPCC 2001) the number of studies of observed trends in the physical and biological environment and their relationship to regional climate change has greatly improved, as has the quality of the data sets. (IPCC 2007) "…confidence has increased that some weather events and extremes will become more frequent, more widespread and/or intense during the 21st century and more is known about the potential effects of such changes" (IPCC 2007). Although evidence to provide policy makers with answers regarding climate change have improved since the 2001 report, many research challenges remain.

3.4 Climate Change in South Africa

The generation of climate scenarios is imperative to any subsequent step in regional impact assessment. This is particularly important when assessing climate change on a regional scale (temporal and spatial) if any decision-making process is to follow based on the outcome. As discussed in previous sections, the core tool for projecting future climate is the General Circulation Model (GCM) that, although effective on a global scale, is not appropriate on a regional scale.

Since the IPCC report (2001) climate model projections have become more sophisticated. The Climate Systems Analysis Group (CSAG) at the University of Cape Town has done extensive work on regional scenarios using empirical and regional downscaling models (Hewitson 1997, Hewitson 1999, Hewitson 2001, Hewitson and Crane 2005a, Hewitson and Crane 2005b). Only projections for the Western Cape, which includes the study area for this project, will be discussed in the following sections. To put the projections into context, a short overview of the existing weather patterns in the Western Cape is discussed first.

3.4.1 The Western Cape climate

The Western Cape has a Mediterranean climate characterised by dry summers and wet winters. This is largely due to the position of the subcontinent relative to the low-pressure systems between 40˚ and 50˚ south (Midgley et al 2005). These low-pressure systems bring winter rainfall to the south-western part of the country by means of a procession of cold fronts, when the westerly waves shift northward. Dry conditions are attributed to variations in the westerly wave and high pressure cells' positions annually. Mountain ranges stretching north-south along the west coast and east-west in the south act as orographic barriers. These topographical features create a dry interior and in the coastal region they also augment the rainfall through orographic rain. The regional climate is also influenced by coastal low pressure systems, resulting in hot, dry ‘berg’ winds, blowing from the interior and causing above normal warm conditions during spring and late winter. Frontal systems sometimes result in cut-off low pressure conditions that may cause extreme rainfall events during spring and autumn. (Preston-Whyte and Tyson 1988; Midgley et al 2005)

3.4.2 Regional climate scenarios: trends and downscaling

Downscaling is the term used to define the development of regional scale projections of change based on the global projections (models used to simulate the global response of the climate system). The tools available for downscaling are either Regional Circulation Models (RCM) or empirical downscaling. Although the research community is able to generate detailed scenarios, the uncertainties and probabilities associated with these scenarios remain undetermined. The downscaling methods are still limited in the magnitude of projected change, but it is a great deal more confident in the qualitative aspects (Midgley et al 2005, Hewitson et al 2005). Midgley et al (2005) lists downscaling as one of the four areas of uncertainty that currently limits the detail of regional projections in Southern Africa. The other three are:

Future emission:

The global response to mitigation strategies on the emission of greenhouse gases can result in projected global mean temperatures varying with up to 4° Celsius.

Uncertainty in science:

Current understanding of the climate system in Africa is limited. This is especially of great concern as Africa is said to be more vulnerable to change. Change of any form inherently impacts on society.

Natural variability:

The relative short historical climate record for Southern Africa (and Africa) makes it difficult to define natural variability in time and space. Historical climate trends are nevertheless used as a foundation for assessing future change. The historical trends are summarised in the following paragraphs.

3.4.2.1 Atmospheric circulation

Hewitson et al (2005) quoted in Midgley et al (2005) analysed circulation patterns during 1958 to 2001 over the Western Cape. The frequency of strong low-pressure systems "has increased significantly during March to May" (Midgley et al 2005) and have decreased during June to August, resulting in spatial changes in rainfall. Fewer intense low pressure systems during winter increased conditions favourable to brown haze and smog days in Cape Town. An increase in hot dry berg winds in September to February due to an increase in the frequency of strong high pressure systems occurred. Accompanied by a weak wind field over the Cape Metropole, these conditions may lead to an increase in inversion layers, trapping emissions from factories and cars.

3.4.2.2 Air temperature

New et al (2005) analysed trends in daily extreme climate over Southern and Western Africa for 1961-2000 and found temperature extremes (statistically significant for most stations) showing patterns of consistent warming. Hot extremes (95^{th} percentile) generally showed trends of greater magnitude than the cold (90^{th} percentile), suggesting a faster change in warmer temperatures than cold. These results were confirmed by Midgley et al (2005). A temperature trend analysis of data over 30 to 40 years for 12 meteorological stations were obtained from the Institute for Soil, Climate and Water. This analysis showed significant warming trends for minimum temperatures during December to March and July to September, and for maximum temperatures during January, May and August. In summary, very warm days have become warmer or have recurred more regularly during the last decade (Midgley et al 2005).

3.4.2.3 Rainfall

Due to high inter-annual variability, rainfall trends are more difficult to analyse than those of temperature. Midgley et al (2005) expanded on preliminary work by Hewitson and Crane (2005a, 2005b). In general, mountainous areas show little change or positive trends, whereas low-lying areas have negative trends (decreased rainfall). Seasonal trends are more complex. Lower rainfall during winter seems likely and is linked to the trends in circulation patterns. The causes of the increased rainfall over the mountains are yet unknown.

3.4.3 Climate projections for the Western Cape

Midgley et al (2005) summarises the projections for the Western Cape based on work by CSAG (Hewitson 1997, Hewitson 1999, Hewitson 2001 and Hewitson et al 2005) and Schulze and Perks (2000).

3.4.3.1 Temperature

Historic data indicate the same trends as indicated by the projections for the future, namely warming in all areas under discussion. In summary, surface air temperatures will increase. Inland regions will experience bigger increases than coastal regions and land surface feedbacks can either be a very significant exacerbation or mitigation factor. Typical increases to be expected by 2050 are ~1.5˚C at the coast and 2-3˚C inland of the mountains.

3.4.3.2 Rainfall

Moisture availability, a suitable mechanism and environmental conditions to induce cloud formation are prerequisites for precipitation. Increased atmospheric moisture (predicted) suggests increased precipitation, should the others factors be in place. Both historical and projected changes however suggest circulation conducive to subsidence – suppressing convective activity. (The mechanism for bringing rain moves south during winter.) This suggests more thunderstorms over the Western Cape.

Figure 10 illustrates projected changes in precipitation. Columns group regional projections from independent global model simulations of the future, from left to right – HadAM3, ECHAM 4.5, CSIRO Mk2, GFDL v2.1, MIROC, MRI. The rows are the months of the year (January at the top, December at the bottom), red tones represent drying, and blue tones wetting. The downscaling of the six GCM's consistently agree that the western regions of the Western Cape (including the study area) will experience a decrease in rainfall in specifically in early winter, with the trend continuing during the latter part of winter (Hewitson and Crane 2005b). Late summer increase in precipitation in the interior and in the east is projected.

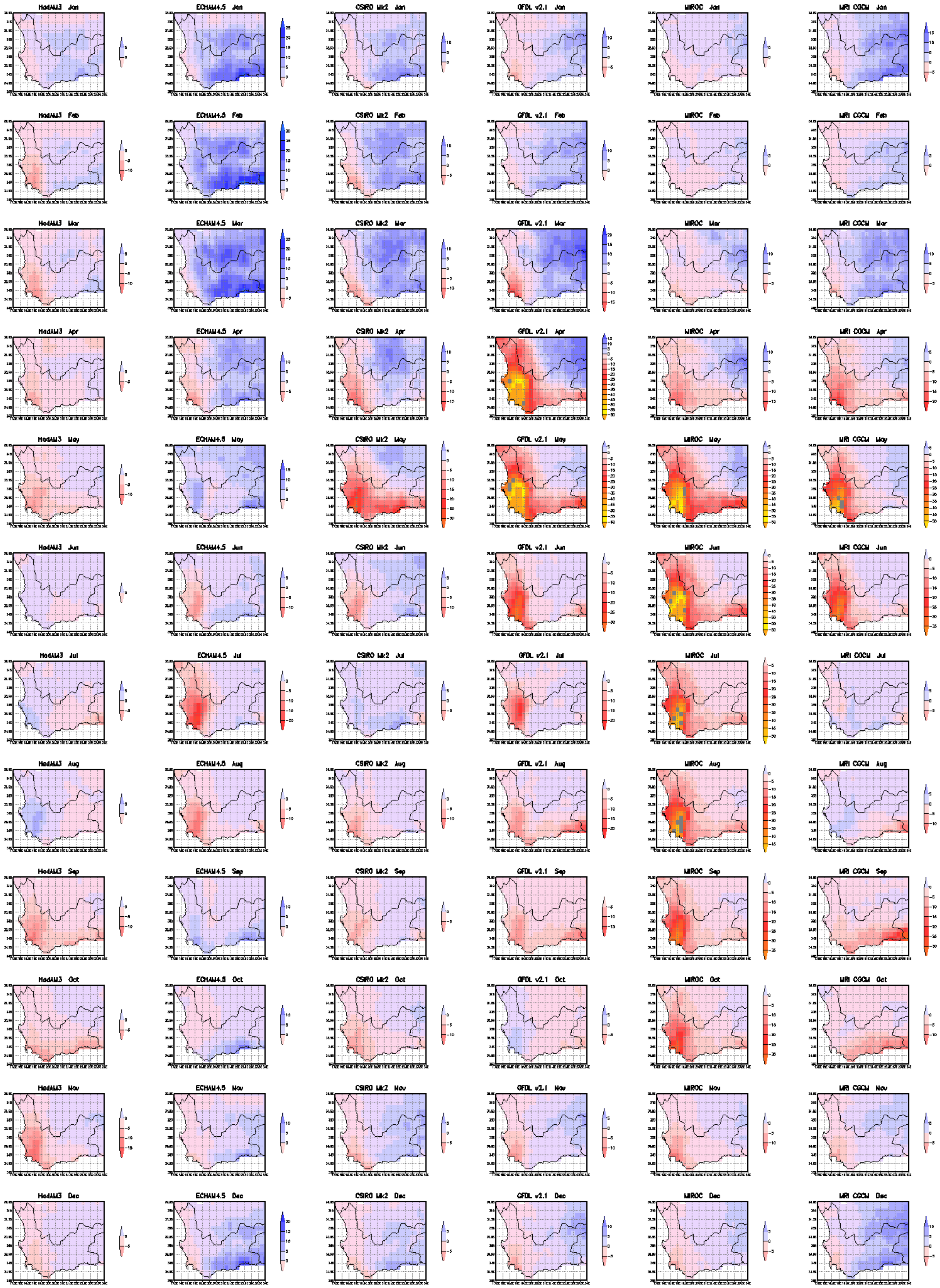

Figure 10: Projected changes in monthly total precipitation (in mm) for, nominally, the period around 2070. Taken from Midgley et al (2005)

The frequency of rain days is expected to remain the same during late summer, but monthly precipitation totals will increase due to more intense rainfall events. Van Wageningen (2006) confirmed an expected increase in occurrence of 24-hour rainfall of larger magnitudes when historical data are compared to forecasted data for selected stations.

3.4.4 Potential impacts of climate change on hydrological responses and associated water resources

When assessing water resources, three aspects are of particular importance, the future availability of water, the future demand and the consequences of both on the environment (Rogers 1994). As the demand for water grows, accurate knowledge of its availability and use become increasingly important. The impacts of droughts, floods and other hydrological perturbations thus have an even greater effect on society. Even under present climatic conditions, southern Africa is already considered a water-scarce country, and the Western Cape is characterised by variability in the abundance of water resources. It is necessary to assess the current hydroclimatic conditions as any climate related changes will be superimposed on these (Schulze 2005, Schulze et al 2005). Many studies have been conducted by Schulze and co-workers in an attempt to quantify these and understand related impacts (Schulze and Perks 2000, Schulze 2003, Schulze 2005, Schulze et al 2005).

3.4.4.1 Background

For the purpose of integrated water resource planning, the country has been divided into 18 Water Management Areas (WMA's). The WMA's are considered as the predecessors to the Catchment Management Agencies (with the same names) that are currently in various stages of being established. (DWAF 2002). The Western Cape consists of the Berg, Breede, Gourits and Olifants-Doorn WMA's. The Cape Winelands District has parts of its jurisdiction areas located in all four, with the bulk of their water being supplied from the Berg, Breede and Olifants-Doorn WMA's.

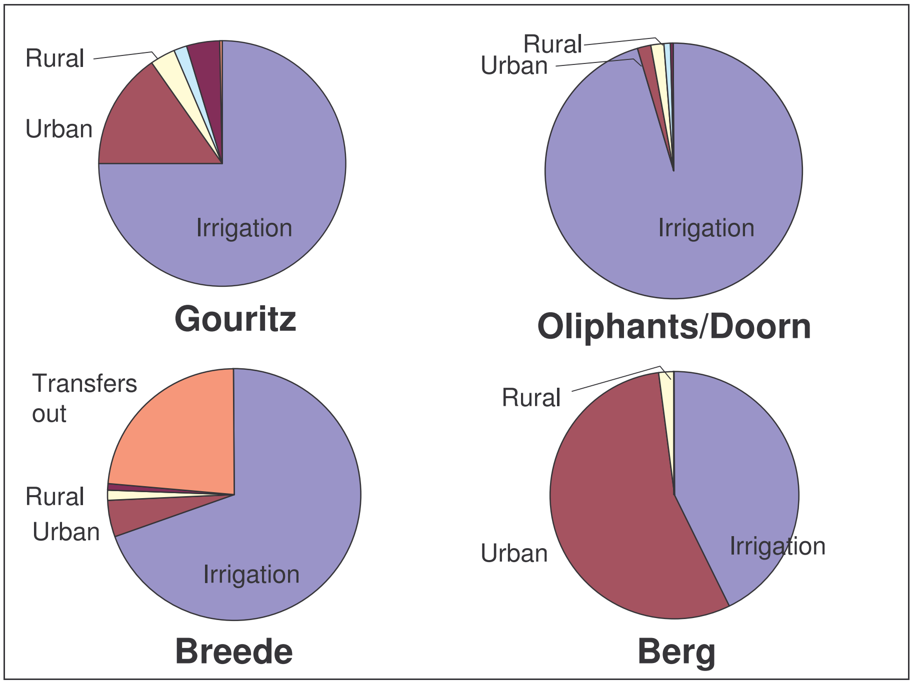

Figure 11: Water use by sector for the four Water Management Areas in the Western Cape (Midgley et al 2005)

Agriculture (irrigation) is the major water user in the Western Cape (Figure 11), except in the Berg WMA which supplies the metropolitan area of Cape Town. The Berg WMA is already in deficit (DWAF 2004) and is expected to be the area to show the highest future population growth. Increasing demand is already putting pressure on resources, specifically the ecological health of the mainstream rivers (DWAF 2004, Barnes 2003).

The Western Cape is already experiencing significant water stress. The abstraction of groundwater as an additional resource from the Table Mountain Group Aquifers is currently being investigated and is approximated at 70 million m^3/annum. The area is thus becoming increasingly vulnerable to variability in climate, ultimately affecting the quality and quantity of water supply.

3.4.4.2 Projected hydroclimatic changes

Generally a warmer and drier local climate will result in an increase in irrigation requirements and a decrease in water availability. A decrease in water availability sometimes implies a decrease in water quality. A general drying is also said to lead to a decrease in groundwater recharge (a 10%

reduction in recharge is expected by 2015 in the southwest of the province)(Schulze et al 2005). A similar reduction in runoff is projected for 2015.

The ecologic integrity of wetlands, rivers and estuaries is expected to be severely compromised and biodiversity reduced (Midgley et al 2005). The indirect impacts of a change in water quality and quantity are far-reaching, and some aspects relating to human health will be discussed in further chapters.

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C H A P T E R 4

Climate Related Hazards and Human Health

4.1 Introduction

There is growing evidence that global climate is changing and will have profound effects on the health and well-being of citizens in countries throughout the world (WHO Regional Office for Europe 2003). Recent evidence suggests that the associated changes in temperature and precipitation are already adversely affecting population health (IPCC 2007).

In the field of human health, climate change poses a major and largely unfamiliar challenge (WHO 2005b). There is an increasing amount of information available to climate change scientists and the assessments of likely changes are no longer based on possible future scenarios and models, but rather on observations on global climate data. Thus the picture of future changes is becoming clearer, but the impact on human health has not yet been determined in depth or with narrow margins of certainty. What is clear, however, is that the increasing understanding of climate change is transforming how we view the determinants of human health (WHO 2003).

The global scale of climate change differs fundamentally from the many other familiar environmental concerns facing humankind, such as localized pollution or microbiological hazards (WHO Regional Office for Europe 2003, WHO 2003). Climate change implies that the earth's biophysical and ecological systems are altering, as evidenced by stratospheric ozone depletion, accelerating losses of biodiversity, increasing stresses on food producing systems, depletion of freshwater supplies and global dissemination of persistent organic pollutants. Thus climate change is increasingly influencing many ecosystems and their inhabitants. To a large extent public health depends on the efficient functioning of such ecosystems. For example: health is closely linked to safe drinking water, sufficient food, secure shelter and stable social conditions. According to the World Health Organization, human health is already being affected by climate change. In the World Health Report 2002 (World Health Report 2002) climate change was already estimated to be responsible for approximately 2.4% of worldwide diarrhoea and 6% of malaria in some middle-income countries in 2000. It remains difficult at present, however, to pinpoint small changes in disease incidence against the background noise of ongoing changes in other causal factors.

There are some fundamental factors that should be borne in mind in any discussion on climate change and the effects that its accompanying processes may have on life on earth and on human health in particular (WHO Regional Office for Europe 2003, WHO 2003).

- Climate change does not cause novel environmental exposures, but may exacerbate the burden of climate-sensitive diseases. The size of the impact will depend on the implementation and effectiveness of timely interventions.
- Climate change results from both natural and human-induced processes. Emissions of greenhouse gases affect human health at different scales. At the local scale, particulate matter emitted by vehicles has harmful effects. At the regional scale, transport of sulfur and nitrogen oxides causes acid deposition. At the global scale, the links between climate change and local environmental factors produce a range of hazards to human health.

4.2 Distinguishing between Weather and Climate when Considering Impact on Health

When considering "climate change and health", the health impacts of several meteorological exposures namely weather, climate variability and climate change should be considered (WHO Regional Office for Europe 2003, WHO 2003).

Weather is the continuously changing condition of the atmosphere, usually considered for a particular location on a time scale that can extend from minutes to weeks (WHO Regional Office for Europe 2003). Climate is the average state (mean and variability) of the lower atmosphere (i.e. general or prevailing weather conditions) and the associated characteristics of the underlying land or water, in a particular region, usually spanning at least several years (WHO Regional Office for Europe 2003). Climate variability is the variation around the average climate, including seasonal variations and large-scale regional cycles in atmospheric and ocean circulations such as the El Niño/ Southern Oscillation (ENSO) or the North Atlantic Oscillation (WHO Regional Office for Europe 2003).

Climate change occurs over decades or longer time-scales. Until now, changes in the global climate have occurred naturally, across centuries or millennia, because of continental drift, various astronomical cycles, variations in solar energy output and volcanic activity. Over the past few decades it has become increasingly apparent that human actions are changing atmospheric composition, thereby causing global climate change (Albritton and Meiro-Filho 2001).

When investigating the impact of weather events and climate variability on human health, "exposure" to meteorological factors should be properly defined. Weather and climate can each be condensed over various time scales or spatial ranges. The appropriate scale of analysis, and the choice of any latent (lag) period between exposure and effect, will depend on present knowledge of or anticipated nature of the relationship (Albritton and Meiro-Filho 2001). Almost all studies on this subject require long-term data on weather/climate and health outcomes on the ***same*** time scales or spatial ranges. For example, it has proven difficult to assess how climate variability and change has influenced the recent spread of malaria in African highlands because the appropriate health, weather and other relevant data (e.g. land use change) have not been collected in the same locations and on the same scales (Githeko et al 2000).

Attention needs to be drawn here regarding the need to accommodate the several types of uncertainty that are inherent in these studies. Many statistical approaches are employed in the analyses of data sets relating climate information to disease data (Bailar and Bailar 2001). Attempts are made to integrate data of varying quality from many disciplines and sources. There is always the danger that such assessments can undermine their own credibility due to oversimplification of underlying assumptions. ***Managing uncertainty is just as important as reducing uncertaint***y (Bailar and Bailar 2001).

There are multiple types of uncertainty that affect both the size of the relationships observed and the attribution of causality to such relationships. The following types of uncertainty have been documented (WHO Regional Office for Europe 2003, Watson et al 2001):

Problems with data:

- Missing data or errors
- "Noise" in the data associated with bias or incomplete observations
- Random sampling error and sampling biases (non-representivity)

Problems with models (assumed relationships between climate and health):

- Known processes but unknown functional relationships or errors in the structure of the model
- Known structure but unknown or erroneous values of some important parameters
- Known historical data and model structure but reasons to believe that the parameters/ model/ relationship between climate and health in general will change over time
- Uncertainty regarding the predictability of the system or effect

- Uncertainty introduced by approximating or simplifying relationships within the model

Other sources of uncertainty:

- Ambiguously defined concepts or terms
- Intermittent exposure to climate hazards and difficulty in categorizing such exposure
- Inappropriate spatial or temporal units (such as data in exposure to climate or weather)
- Inappropriateness of or lack of confidence in the underlying assumptions
- Uncertainty resulting from projections of human behaviour (such as future disease patterns or technological change) in contrast to uncertainty resulting from "natural" sources (such as climate sensitivity

Predictions about how complex systems such as regional climate systems and climate-dependent ecosystems will respond when pushed beyond critical limits are necessarily uncertain. Likewise, there are uncertainties about the future characteristics, behaviours and coping capacity of human populations.

Risk assessment is often discussed as if the process will deliver only one answer. In reality this is far from true (Bailar and Bailar 2001). When would it be prudent policy to trigger a response to a hazard? Some people and organizations want to wait before they act to see if real consequences ensue, while others require much lower levels of risk to treat the situation as potentially dangerous. Neither extreme can be upheld under all circumstances, because risk management must integrate health risk assessment with other aspects such as economic imperatives, legal mandates and constraints, levels of public concern and the availability of substitutes for the potential hazard (Bailar and Bailar 2001).

In practice, the level of risk that triggers an intervention may differ between different exposure settings. For example, a one in a million excess risk of some adverse response may be deemed acceptable for environmental exposures of the entire population, whereas a risk of one in a thousand may be deemed acceptable for some occupational exposures (we accept a higher risk than that for professional divers and firefighters), and one in ten may be acceptable for a medical intervention in desperate circumstances (Bailar and Bailar 2001). Society accepts many risk-benefit tradeoffs, such as those implicit in driving or flying. In essence, exposure levels are set at levels that are deemed to provide an acceptable tradeoff between societal benefits and risks (Bailar and Bailar 2001). This fact has serious implications for many analytic models and should be borne in mind when analyzing the relationships between exposure and the risks inherent in climate-based hazards.

4.3 Health Impacts of Climate Change in general

In the early 1990s there was little awareness of the health risks posed by global climate change (WHO Regional Office for Europe 2003). This reflected a general lack of understanding of how the disruption of biophysical and ecological systems might affect the long-term well-being and health of populations. There was little awareness among natural scientists that changes in their particular objects of study – climatic conditions, biodiversity stocks, ecosystem productivity, and so on – were of potential importance to human health. Indeed, this was well reflected in the meagre reference to health risks in the first major report of the United Nations Intergovernmental Panel on Climate Change (IPCC), published in 1991.

This situation has now changed substantially. The IPCC Second Assessment Report (1996) devoted a full chapter to the potential risks to health (IPCC 1996) The Third Assessment Report (2001) did likewise (IPCC 2001), this time including discussion of some early evidence of actual health impacts, along with assessing potential future health effects. That report also highlighted the anticipated health impacts by major geographic region.

Broadly, a change in climatic conditions can have three kinds of health impacts (WHO Regional Office for Europe 2003):

- Those that are relatively direct, usually caused by weather extremes. [DIRECT]
- The health consequences of various processes of environmental change and ecological disruption that occur in response to climate change. [INDIRECT]
- The diverse health consequences – traumatic, infectious, nutritional, psychological and other – that occur in demoralized and displaced populations in the wake of climate-induced economic dislocation, environmental decline, and conflict situations. [MULTI-STAGE]

Our understanding of the impacts of climate change and variability on human health has increased considerably in recent years (WHO Regional Office for Europe 2003, IPCC 1991, IPCC 1996, IPCC 2001, Patz et al 2000). Several basic issues however complicate the assessment of these impacts:

- Climatic influences on health are often modulated by interactions with other ecological processes, social conditions, and adaptive policies. In seeking explanations, a balance must be sought between complexity and simplicity.
- There are many sources of scientific and contextual uncertainty. The IPCC has therefore sought to formalize the assessment of level of confidence attaching to each health impact statement (IPCC 2001). Many other studies however, do not follow such a classification system of risks.
- Climate change is one of several concurrent global environmental changes that simultaneously affect human health – often interactively (Patz et al 2000, Ebi et al 2006, Watson et al (eds) 1998). A good example is the transmission of vector-borne infectious diseases, which is jointly affected by climatic conditions, population movement, forest clearance and land-use patterns, biodiversity losses (e.g., natural predators of mosquitoes), freshwater surface configurations, and human population density (Gubler 1998).

For each potential impact of climate change, certain groups will be particularly vulnerable to disease and injury. The vulnerability of a population depends on factors such as population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care (Woodward et al 2000).

The growing body of research literature underscores that our understanding of the links between climate, climate change and human health has increased considerably over the last ten years. However, there are still many gaps in knowledge about likely future patterns of exposure to climatic-environmental changes, and about the vulnerability and adaptability of physical, ecological and social systems to such climate change.

4.4 Epidemiological aspects of the study of health impacts of climate change

Epidemiological assessment studies on climate change and health encompasses basic studies of causal relationships, risk assessment, evaluation of population vulnerability and adaptive capacity, and the evaluation of intervention policies.

The challenges in identifying, quantifying and predicting the health impacts of climate change entail issues of scale, "exposure" specification, and the elaboration of often complex and indirect causal pathways (Walther et al 2002).

The ***first challenge*** entails the geographic scale of climate-related health impacts and the typically wide time spans that are unfamiliar to most health-related researchers (Walther et al 2002). Epidemiologists usually study problems that are geographically localized, have relatively rapid onset and directly affect health.

Secondly, the “exposure” variable – comprising weather, climate variability and climate trends – poses difficulties (Walther et al 2002). There is no obvious "unexposed" group to act as baseline for comparison. Indeed, because there is little difference in weather/climate exposures between individuals in the same geographic locale, comparing sets of persons with different “exposures” is usually precluded. Rather, whole communities or populations must be compared – and, in so doing, attention must be paid to inter-community differences in vulnerability. For example, the excess death rate during the severe 1995 Chicago heat wave varied greatly between neighbourhoods because of differences in factors such as housing quality and community cohesion (Centers for Disease Control and Prevention 1995).

Thirdly, some health impacts occur via indirect and complex pathways (Walther et al 2002). For example, the effects of temperature extremes on health are direct. In contrast, complex changes in ecosystem composition and functioning help mediate the impact of climatic change on transmission of vector-borne infectious diseases and on agricultural productivity.

A ***final challenge*** is the need to estimate health risks in relation to future climatic-environmental scenarios. Unlike most recognized environmental health hazards, much of the anticipated risk from global climate change lies years to decades into the future.

The choice of non-climatic variables will depend on the specific disease, but the principal categories of confounding or modifying factors include (WHO 2003, WHO 2005b)(Table 3):

- Age structure of population
- Underlying (pre-existing) rates of disease, especially cardiovascular and respiratory diseases and diarrhoeal illness as well as prevalence of HIV/AIDS
- Level of socio-economic development
- Environmental conditions, e.g. land-use, air quality, housing conditions
- Quality and/or accessibility of health-care
- Specific control measures, e.g. vector control programmes

Table 3: Data required to monitor climate impacts on health (WHO 2005b)

	Thermal extremes	**Extreme weather events (floods, high winds, droughts)**	**Food- and waterborne disease**	**Vector-borne disease**
Principal health outcomes	Daily mortality; hospital admissions; clinic/ emergency room attendance	Attributed deaths; hospital admissions; infectious disease surveillance data; mental health; nutritional status	Relevant infectious disease deaths and morbidity	Vector populations; disease notifications; temporal and geographical distributions
Which populations/ locations to monitor	Urban and peri-urban populations, especially in developing countries	All regions	All regions	Margins of geographical distribution (e.g.: changes with latitude, altitude) and temporality in endemic areas
Sources and methods for acquiring health data	National and sub-national death registries (e.g. city specific data)	Use of sub-national death registries; local public health records	Death registries; national and subnational surveillance notifications	Local field surveys; routine surveillance data (variable availability)
Meteorolo-gical data	Daily temperatures (min/max or mean) and humidity	Meteorological event data: extent, timing and severity	Weekly/daily temperature; rainfall for water-borne	Weekly/daily temperature, humidity and rainfall
Other variables	Confounders: influenza and other respiratory infections; air pollution Modifiers: housing conditions (e.g. household/work-place air conditioning), availability of water supplies	Disruption/contamination of food and water supplies; disruption of transportation. Population displacement The above parameters will have an indirect impact on health	Long term trends dominated by host-agent interactions whose effects are difficult to quantify. Indicators may be based on examination of seasonal patterns.	Land use; surface configurations of freshwater

Considerable research is currently being conducted to elucidate linkages between climate and epidemics (WHO 2005b). Of the 14 diseases meeting the defined criteria for potential for climate-informed early warning systems (EWS), few (african trypanosomiasis, leishmaniasis and yellow fever) are not associated with some sort of EWS research or development activity (WHO 2005b). For West Nile virus, an operational and effective warning system has been developed which relies solely on detection of viral activity, and it remains unclear whether the addition of climatic predictors would improve the predictive accuracy or lead-time. For the remaining diseases (cholera, malaria, meningitis, dengue, Japanese encephalitis, St Louis encephalitis, Rift Valley Fever, Murray Valley encephalitis, Ross River virus and influenza), a temporal link between climatic factors and variations in disease rates has been demonstrated (Gubler 1998, WHO 2005b).

This report (WHO 2005b) suggests a number of likely explanations for the lack of full descriptions of climate-based early warning systems being used to influence disease control decisions:

- Affordable and accessible data and analytical tools have only recently become widespread, so that this field is at a relatively early stage of development and new studies are now being published at a rapid rate
- As yet, there is no common consensus on good practice in building predictive models, or on assessing their accuracy and lead-times: as a consequence it is often difficult to judge the utility of existing models
- Most research projects have had relatively limited resources and therefore have not been tested in locations outside the original study area
- Many studies in this area focus solely on climatic factors and do not explicitly test other hypotheses that might explain variations in disease rates over time
- Many studies are undertaken as “pure research”, therefore, neither the extent to which they address specific control decisions nor their potential utility for planning public health interventions is clear.

The health impacts of future climate change, including changes in climatic variability, can be estimated in two main ways (WHO 2003, World Health Report 2002). Firstly, we can extrapolate from analogue studies that treat recent climatic variability as a foretaste of climate change. Second, we can use predictive computer models based on existing knowledge about relationships between climatic conditions and health outcomes. Such models cannot predict exactly what will happen, but they indicate what would occur if certain future climatic (and other specified) conditions were fulfilled.

In order to further develop the science of health impact prediction related to climate change, the five main tasks facing researchers are (WHO 2003, World Health Report 2002) listed in the following sections.

4.5 Establishing baseline relationships between weather and health

There are many unresolved questions about the sensitivity of particular health outcomes to weather, climate variability, and climate-induced environmental changes. For example, the major pathogens that cause acute gastroenteritis multiply faster in warmer conditions.

4.5.1 Seeking evidence of early effects of climate change

There have been many observations on physical and ecological changes attributable to recent global warming – but few indications yet of human health effects. Amongst these are changing patterns of infectious disease (such as tick-borne encephalitis (Pascual 2000) and cholera (IPCC 2001)). Health researchers must allow for the fact that humans have many coping strategies, ranging from planting shade trees, to changing work-hours or to installing air-conditioning.

The challenge is to pick the settings, populations and health outcomes with the best chance of: (i) detecting changes, and (ii) attributing some portion of these to climate change. Impacts are likely to be clearest where the exposure-outcome gradient is steepest, the local population's adaptive capacity is weakest, and when there are few competing explanations for observed relationships.

4.5.2 Scenario-based predictive models

Unlike most other environmental exposures, we know that the world's climate will continue to change for at least several decades. Climatologists now can satisfactorily model the climatic consequences of future scenarios of greenhouse gas emissions. By linking these climate scenarios with health impact models we can estimate the likely impacts on health (WHO Regional Office 2003).

Some health impacts are readily quantified (deaths due to storms and floods for instance) where others are more difficult to quantify (e.g., the health consequences of food insecurity). Models are needed with sufficient representation of the multi-faceted future world to provide useful, or credible, estimates of future health risks. Where possible, a high level of "integration" should be employed to achieve realistic modeled forecasts of impact in a world that will have undergone various other demographic, economic, technological and social changes.

4.5.3 Evaluating adaptation options

Adaptation means taking steps to reduce the potential adverse impact of environmental change. Many adaptive measures have benefits beyond those associated with climate change. The rebuilding and maintaining of public health infrastructure is often viewed as the "most important, cost-effective and urgently needed" adaptation strategy (IPCC 2001). This includes public health training, more effective surveillance and emergency response systems, and sustainable prevention and control programs.

Extreme weather events can have vastly different impacts because of differences in the target population's coping capacity (IPCC 2001). Climate-related adaptation strategies must therefore be considered in relation to broader characteristics – such as population growth, poverty, sanitation, health care, nutrition, and environmental degradation – that influence a population's vulnerability and capacity to adapt.

Adaptations which enhance a population's coping ability may protect against current climatic variability as well as against future climatic changes (IPCC 2001). Such adaptations may be especially important for less developed countries with little current coping capacity.

4.5.4 Estimating the co-incidental benefits and costs of mitigation and adaptation (Stern 2006)

Steps to reduce greenhouse gas emissions (mitigation) or to lessen health impacts (adaptation) may have other coincidental health effects. For example, promotion of public transport relative to private vehicles may not only reduce CO_2 emissions, but also improve public health in the near-term by reducing air pollution and road traffic injuries and increasing physical activity. Information about these "ancillary" costs and benefits is important for policy-makers. Note, however, that for impacts that are either deferred in time or that extend into the distant future, the costing is not straightforward.

4.5.5 General issues concerning uncertainty

Researchers should describe, communicate and explain all relevant uncertainties. This gives the decision-maker important insight into the conditions needed for a particular outcome to occur. Since environmental risk perception varies with culture, values and social status, “stakeholders” should assist both in shaping the assessment questions and in interpreting the risk.

The future burden of disease attributable to climate change will depend in part on the timeliness and effectiveness of the interventions implemented and such interventions should be aimed at interrupting the pathways by which adverse factors lead to ill-health (IPCC 2007). A brief review follows of the main pathways playing a role in both the present and future effects of climate change as well as in the development of vulnerability of human populations to climate change.

4.6 Pathways to ill health

There are close relationships between ill health, poverty and vulnerability at population, community and personal levels. Furthermore, these relationships are extraordinary complex and interwoven. Many aspects of poverty have a negative impact on health and on access to effective health services. In turn, ill health can affect the productivity of individuals, households and communities, making it more likely that they will fall into poverty or be unable to escape poverty (Mhalu 2005, Russel 2004).

How individuals, households and communities respond to risks and manage adverse events directly impacts on the pathways through which ill health reduces economic capacity and increases the burden of disease (Goudge and Govender 2002). Important factors in this response to risk are the nature of the adverse event (e.g. duration, severity and repetition of the event) and who is affected (adult, child) and their role in the household (e.g. breadwinner, carer, dependant)(Goudge and Govender 2002). Responding to vulnerability in effective ways is critical in reducing the effects of adverse processes such as climate change. Focusing on curative care and health service provision are important, but not enough. Wide-ranging support and livelihood protection are needed, but the governments most likely to need implementation of large-scale interventions are also the least able to do so, namely the developing nations (IPCC 2007). The latest IPCC report explicitly emphasizes that the people who are likely to be affected most are the world's poorest (IPCC 2007). As a group, they are also the people who have done the least to increase the levels of greenhouse gases worldwide.

Table 4: Direct and indirect potential effects on health of changes in temperature and weather (Adapted from: Haines et al (2000))

Mediating Process	Health outcome
Direct effects	
Exposure to thermal extremes	Changed rates of illness and death related to heat and cold
Changed frequency or intensity of other extreme weather events	Deaths, injuries, psychological disorders; damage to public health infrastructure
Indirect effects (disturbances of ecological systems)	
Effect on range and activity of vectors and infective parasites	Changes in geographical ranges and incidence of vector-borne disease
Changed local ecology of water-borne and food-borne disease	Changed incidence of diarrhoeal and other infectious diseases
Changed food productivity (especially crops) through changes in climate and associated pests and diseases	Malnutrition and hunger (or increase sector of population malnourished) with consequent poor recovery from illness and impairment of child growth and development
Sea level rise with population displacement and damage to infrastructure	Increased risk of infectious disease, psychological disorders
Biological impact of air pollution changes (including pollens and spores)	Increase in asthma and allergies; other acute and chronic respiratory disorders and deaths
Social, economic and demographic dislocation through effects on economy, infrastructure and resource supplies	Wide range of public health consequences: mental health and nutritional impairment, infectious diseases, civil unrest

Table 4 lists the direct and indirect potential effects of changes in temperature and specifically refers to the disturbance of ecological systems. The complex pathways from driving forces through exposure to potential health impacts are further simplified in the diagram below, originally published by Patz et al (2000) and modified by the WHO and other authors since (IPCC 2007, WHO 2003).

4.6.1 Microbial contamination pathways and other disease transmission dynamics

A very brief outline of the pathways of disease transmission will be given for the sake of clarity, so that the difficult choices regarding the many points of interruption of these pathways can become clearer. This is not meant to be an in-depth review.

Several different classifications exist for the routes of transmission of different infections (Carr and Strauss 2001, Giesecke 2002). They have been generated mostly for the purpose of grouping similar diseases together and none of them is entirely satisfactory. Common classifications include person-to-person spread, air-borne, water-borne, food-borne and vector-borne infections.

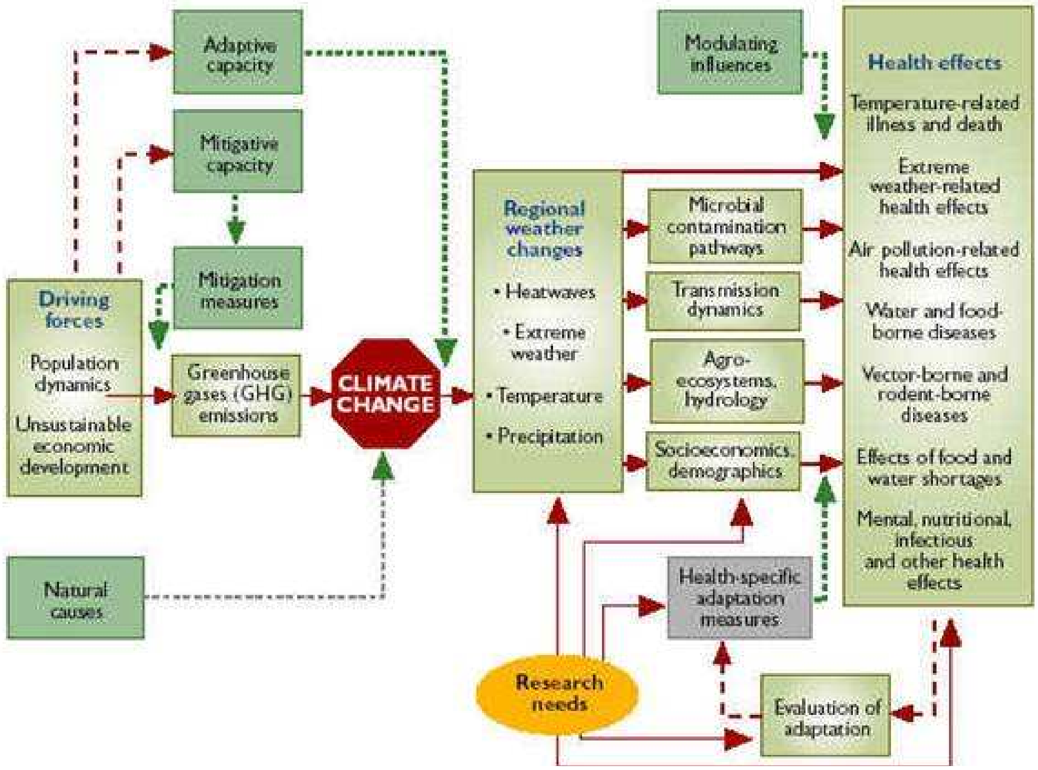

Figure 12: Climate change and health: pathway from driving forces through exposure to potential health impacts (adapted by the WHO (WHO 2003) from Patz et al (2000) (Ebi et al 2006)

An alternative approach would be simply to divide the infections into those that are transmitted directly or indirectly (Giesecke 2002). Table 5 contains some examples.

The main organisms that pose a threat to health are pathogenic bacteria, viruses, protozoa and helminths (Giesecke 2002). Many of these organisms (e.g. some viruses, protozoa) have low infectious doses - that means that only a few of these organisms are needed to infect a new host. The infective dose varies between organisms and with respect to the susceptibility of the exposed individual.

Table 5: Examples of directly and indirectly transmitted infections (adapted from Jawetz et al 1987)

Direct transmission	**Indirect transmission**
Mucous membrane to mucous membrane: e.g. sexually transmitted diseases	Contaminated water - e.g. hepatitis A
Across placenta: e.g. toxoplasmosis	'Proper" air-borne: e.g. chicken pox
Transplants, including blood transfusions: e.g. hepatitis B	Vectors: e.g. malaria
Skin to skin: e.g. Herpes type I	Food-borne: e.g. *Salmonella, Escherichia coli*
Sneezes, coughs: e.g. influenza, tuberculosis	Objects: e.g. scarlet fever (toys in nursery)

In addition, there are abundant opportunistic organisms normally occurring in nature such as in water bodies and water courses (Carr and Strauss 2001, Giesecke 2002). Cyanobacteria (blue-green algae) can produce toxins affecting people who come into contact with such water. Algal toxins can also enter the food chain, e.g. by means of contaminated shellfish. Cooking has no effect on many toxins and may not even destroy all of the other pathogens present either.

Disease transmission is affected by the characteristics and behaviour of human hosts (Giesecke 2002, Jawetz et al 1987). The immunity of the host plays an important role. This immunity can be natural or as a result of a prior infection or vaccination. The nutritional status and general health status of the human host also plays an important role. The age and gender of humans exposed to infections can influence their immune status and susceptibility to infections, while personal hygiene and food hygiene are directly related to risk of infections.

It is thus clear that the susceptibility of individuals varies as well as the virulence of the disease-causing organism. It is therefore important to relate an impact or an intervention to the burden of disease or the reduction of this burden. One should take into account the most vulnerable groups within a population or within an area when assessing the impact of disease or when judging the effectiveness of efforts to ameliorate the situation (WHO Regional Office for Europe 2003). For instance, for vulnerable groups the infectious dose may be considerably lower than for the population as a whole. Vulnerable groups such as the malnourished, the immuno-compromised, the elderly or the very young need special consideration when assessing the future impact of pathways of disease affected by climate change.

4.7 Links between 'environment' and 'disease'

Identifying causal relationships is of central importance in Epidemiology, as indeed in all studies of illness and health. Detection of causal relationships indicates points where this chain of events may possibly be interrupted or prevented. On the other hand, if a factor is erroneously identified as a cause, fruitless efforts could be spent in prevention. Thus, epidemiological studies typically examine the possible associations between an exposure variable and disease outcome (Lucas and McMichael 2005). The first formalization of the criteria to prove the causal nature of an observed association was published by Sir Austin Bradford Hill (Hill 1965) and remains a ground-breaking paper in this field. Bradford Hill did not prescribe his proffered criteria as rules that should be fulfilled before an association can be judged as causal, but rather as ways of examining if cause and effect is the reasonable inference from the evidence on the table.

The Bradford Hill approach is unfortunately not enough to deal with the contemporary issues of climate change and health effects (Lucas and McMichael 2005). Formal criteria for causal evidence may steer current research towards comfortable, tightly specified research questions and thus deter scientists from considerations of the "big picture" where the data are often fuzzy and residual confounding likely. Funding bodies may prefer to award research grants to proposals with clear delineation of both exposure and health outcomes and with a study design conducive to causal inference (Lucas and McMichael 2005). This may be one of the reasons why the best studied link between climate change and a particular health outcome is the malaria model.

With the advent of climate related health studies, the notion of 'cause' had become more complex (Keeling and Rohani 2007, Keeling 2001). The roles of chance, bias and confounding considerably complicate causal inferences from population-level data bases of exposures and health consequences of inter-linked environmental and social change processes (Keeling and Rohani 2007). These population-based causal inferences cannot, in general, be reducible to the level of the individual or even to local areas.

Predictive ability of basic models of disease dynamics has improved in recent years (Keeling and Rohani 2007, Keeling 2001). The modelling has moved from simple differential equations to complex models where spatial structure, seasonal "forcing", or stochasticity influence the dynamics and where computer simulation needs to be used to generate theory (Keeling and Rohani 2007).

These sophisticated modelling techniques are a valuable component of public health planning as well as planning of responses to future health disasters. Unfortunately the skills to properly employ these sophisticated techniques are often unavailable in the developing world, where they would have been particularly valuable to prevent the consequences of large-scale climate-induced health crises.

4.8 Attributable burden of climate change

Projecting mortality or morbidity into the future is difficult (WHO Regional Office for Europe 2003). In short term forecasts, such as the effects of the HIV/AIDS epidemic, predictions are modelled to estimate the course of the epidemic. Another example is the predictions of future number of lung cancer cases based on current rates of smoking.

Projecting the potential health impact of climate change requires a different approach since the object is to estimate the impact of different types of future climate exposures on different future disease patterns at specific times in the future (Regional Office for Europe 2003). At the simplest level the burden of disease attributable to climate change can be calculated as (Regional Office for Europe 2003):

***Attributable burden of climate change* = [Estimated burden of disease under climate change scenario] – [estimated burden under a baseline climate, such as that in 1961-1990]**

This simple equation implies that nothing changes in the future except climate. This is not likely to be realistic, but it does single out the contribution of climate from the many other factors that determine the burden of disease.

An even more important calculation (again simplified for illustration purposes) is the portion of the burden of disease that can be avoided by implementing adaptive actions to reduce the impact of climate change (Regional Office for Europe 2003).

***Avoidable burden of climate change* = [Estimated burden of disease under "business as usual" climate scenario] – [estimated burden of disease under a stabilization climate scenario]**

Models of the impact of climate change on health have been developed along those broad lines described by the simplified formulae above (Regional Office for Europe 2003). The models all need reliable data of integrated health risk assessments over fairly long time periods. These are usually not available for developing nations such as South Africa and also almost never available on a regional basis.

Robust estimates of future health impacts rely on reliable projections of future disease patterns (Kovats et al 2005). The application of standardised and established methodology has been developed to quantify the impact of climate change in relation to different greenhouse gas emission scenarios (WHO Regional Office for Europe 2003, Kuhn et al 2005). All health risk assessments are, however, necessarily biased towards conservative best-estimates of health effects that are easily measured (Kuhn et al 2005). Global, regional and national risk assessments cannot take into account irreversibility, or plausible low-probability events with potentially very high burdens of disease. There is no "safe limit" of climate change with respect to future health impacts as health systems in some regions of the world already do not cope adequately with current climate variability (Kuhn et al 2005). Kovats et al (2005) argue that more research is needed to improve methods of risk assessment in order to estimate avoidable deaths and disease, but that the present large uncertainty about future health effects should be a reason to reduce greenhouse gas emissions, not a reason for inaction.

4.9 Health effects of climate change

There are health outcomes that are acknowledged to be associated with weather and/or climate. (WHO Regional Office for Europe 2003, IPCC 2007, WHO 2003, Patz et al 2000, Ebi et al 2006, Watson et al (eds) 1998, Environmental and Workplace Health 2005, National Assessment Synthesis Team 2000). Most of these health outcomes are illnesses and deaths associated with temperature, extreme precipitation events, air pollution, water contamination and diseases carried by mosquitoes, ticks and rodents (see Table 6 - adapted from Environmental and Workplace Health (2005)). Because human health is intricately bound to weather and the many complex natural systems it affects, it is probable that projected climate change will have measurable impacts, both beneficial and adverse, on health (National Assessment Synthesis Team 2000). However, health outcomes in response to climate change are highly uncertain. Currently available information suggests that a range of negative health impacts is possible (WHO Regional office for Europe 2003, IPCC 2007, WHO 2003, National Assessment Synthesis Team 2000). These have been the focus of much of the public health research on climate change to date.

It is important to stress that some positive health outcomes, notably reduced cold-weather mortality, are possible, although the balance between increased risk of heat-related illnesses and death and possible downward changes in winter illnesses and death under a warming scenario cannot yet be confidently assessed (National Assessment Synthesis Team 2000). At present, much of the United States population, for instance, is protected against adverse health outcomes associated with weather and/or climate, although certain demographic and geographic populations are at greater risk (Patz et al 2000, Ebi et al 2006). Adaptation measures should help to protect the US population from adverse health outcomes of projected climate change. These adaptation measures primarily function through the maintenance and improvement of public health systems and the responsiveness of these systems to changing climate conditions and to already identify vulnerable subpopulations. The costs, benefits and availability of resources for such adaptation will have be considered carefully, and further research into key knowledge gaps on the relationships between climate/weather and health is needed (Patz et al 2000, Ebi et al 2006, National Assessment Synthesis Team 2000).

The following brief synthesis of climate-mediated disease has been summarized from the United States (Patz et al 2000, Ebi 2006, National Assessment Synthesis Team 2000) and Canadian official summaries (National Assessment Synthesis Team 2000). All other sources are referenced at point of citation in the following synthesis.

4.9.1 Temperature-related illness and death

Heat stroke, heat exhaustion and other health effects associated with exposure to extreme and prolonged heat appear to be related to environmental temperatures above those to which the population is accustomed. Thus, the regions most sensitive to projected increases in severity and frequency of heatwaves are likely to be those in which extremely high temperatures occur only irregularly.

Within heat-sensitive regions, populations in urban areas are most vulnerable to adverse heat-related health outcomes. Heat indices and heat-related mortality rates are higher in the urban core than in surrounding areas. Urban areas remain warmer throughout the night compared to outlying suburban and rural areas. The absence of night-time relief from heat for urban residents is a factor in excessive heat-related deaths. The elderly, young children, the poor, and people who are bedridden, those on certain medications, or who have certain underlying medical conditions such as cardiovascular disease are at particular risk.

Overall death rates are higher in winter than in summer, and it is possible that milder winters could reduce deaths in winter months. However, the relationship between winter weather and mortality is difficult to interpret. For example, many winter deaths are due to respiratory infections such as influenza, and it is unclear how influenza transmission would be affected by higher winter temperatures. The net effect on winter mortality from climate change is therefore extremely uncertain.

A proportion of the “acute” effect of heat episodes on mortality may be the hastening of death in already ill people by a few days or weeks. This mortality displacement effect can sometimes be seen in the lower than expected mortality immediately following a heat-wave. The key question is what proportion of deaths was brought forward by more than a matter of days or weeks? Assumptions on short-term mortality displacement should be clearly stated if the risk assessment quantifies mortality outcomes.

The population-attributable fraction can be estimated from the slope of the temperature–mortality relationship and the proportion of degree–days that occur above the threshold temperature for each climate scenario. Simply directly applying the change in mean temperature to the temperature–mortality relationship is not recommended.

A key assumption in estimating future impact is whether the population acclimatizes to changes in climate. Changes in population vulnerability and adaptive processes are predicted to substantially influence the burden of mortality and morbidity attributable to the direct effects of thermal extremes. For example, the WHO assessment of the global burden of disease incorporated an assumption regarding acclimatization of the populations to the changing climate that reduces the impact of climate change (Campbell-Lendrum et al 2003).

Episodes of extreme heat already pose a health threat in many parts of the world. For example, following a five-day heat wave in 1995 in which maximum temperatures in Chicago, Illinois ranged from 93 to 104ºF, the number of deaths increased 85% over the number recorded during the same period of the preceding year (Centers for Disease Control and Prevention 1995). At least 700 excess deaths (deaths in that population beyond those expected for that period of time) were recorded, most of which were directly attributable to heat. The International Red Cross Federation reported that the 2003 European heat waves resulted in up to 35 000 deaths, mostly in persons over 75 years of age. It is predicted that between 8000 and 15 000 Australians will die annually by 2100 should greenhouse gas emissions not be mitigated (CANA 2006).

4.9.2 Extreme weather related health effects

Injury and death are the direct health impacts most often associated with natural disasters such as floods and hurricanes. During a flood or hurricane many people die due to physical injuries, mostly cased by debris in flood water or the being swept against hard objects. Secondary health effects have also been observed. These effects are mediated by changes in ecological systems (such as bacterial and fungal proliferation) and in public health infrastructures. Following a sudden-onset disaster, the protection of water supplies and providing safe food is of utmost importance.

4.9.2.1 Extreme weather and the protection of water supplies

Water sources are exposed to a variety of hazards that may damage or contaminate them, but they can be protected against disasters to some extent. It is useful to distinguish between large-scale, formal water-supply systems and small-scale, scattered supplies. The distinction is not so much between urban and rural areas as one based on the level of technology and the institutional arrangements for management, maintenance, and protection (WHO 1997, WHO 2002).

Roof catchment systems are often damaged by wind in storms. People who depend on canals are vulnerable to chronic and acute illnesses where sewage systems were damaged where the canal drains an industrial zone or when poisoning from the release of toxic chemicals occur. Pipes or canals may also be easily washed away or broken during floods, cutting water supplies. Shallow wells in areas with a high water table are more prone to contamination from flooding than are deep boreholes. They may also dry up sooner in a drought. Hillside springs may be destroyed in a landslide. Wells near rivers can be contaminated and filled with sand during unusual flash flooding. All piped systems are subject to breaks and disruption during earthquakes, landslides or civil strife.

In addressing the water needs of a community hit by disaster, consultation with water users should take place as a matter of priority. Many people use multiple sources of water. Some will prefer certain sources for drinking water and others for washing, bathing, watering animals and irrigation. Wherever a hazard or the potential for disruption of the water supply exists, the primary health-care workers or other disaster management staff should discuss alternative drinking-water sources with the people concerned. After implementation, the alternative sources should be visited regularly to check on their status to detect undesirable extraction practices and potential pollution early.

Contingency plans for speedy ensuring of the safety of drinking water reserves should be in place. These will usually involve stockpiling a limited amount of disinfectant chemicals (taking into consideration the shelf-life of these chemicals), plus fencing of the source. The first priority should always be water for drinking, cooking and personal hygiene. (WHO 2002, WHO 2005a)

4.9.2.2 Safe food

Food safety problems vary in nature, severity and extent, and depend on the situation during the emergency or disaster. For example, during floods and hurricanes, food may become contaminated by surface water that has itself been contaminated by sewage and wastewaters. Floodwaters often pick up large quantities of waste and pathogenic bacteria from farms, sewer systems, latrines and septic tanks. The crowding of survivors after disasters may aggravate the situation, particularly if sanitary conditions are poor. (WHO 2002, WHO 2005a).

Any breakdown in vital services, such as water supply or electricity, also severely affects food safety. In the absence of electricity, cold storage may be more difficult if not impossible, and foods may be subject to bacterial growth. This may happen in any stage of the food chain, from production to consumption. Lack of safe drinking water and sanitation hampers the hygienic preparation of food and increases the risk of food contamination. While contamination can occur at all points of the food chain, inadequate washing, handling and cooking of food just before consumption are still prime causes of food borne disease.

Table 6: Potential effects of climate change on health concerns (Adapted from Environmental and Workplace Health 2005).

Health Concerns	Examples of Health Vulnerabilities
Temperature-related morbidity and mortality	Cold and heat related illnesses
	Respiratory and cardiovascular illnesses
	Increased occupational health risks
Health effects of extreme weather events	Trauma cases and disaster-related illnesses
	Damaged public health infrastructure
	Social and mental health stress due to disasters
	Occupational health hazards
	Population displacement
Air pollution-related health effects	Changed exposure to outdoor and indoor air pollutants and allergens
	Asthma and other respiratory diseases
	Heart attacks, strokes and other cardiovascular diseases
	Cancer
Health effects of water- and food-borne contamination	Gastrointestinal disease (especially diarrhoea), skin infections, respiratory infections and hepatitis
	Toxic reactions caused by chemical and biological contaminants
Vector-borne and zoonotic diseases	Changed patterns of diseases caused by bacteria, viruses and other pathogens carried by mosquitoes, ticks and other vectors
Health effects of exposure to ultraviolet rays	Skin damage and skin cancer
	Cataracts
	Disturbed immune function
Population vulnerabilities in rural and urban communities	Aged persons
	Children
	Chronically ill people, chronically malnourished people
	Low income and homeless people
	Disabled and mentally ill people
	Subsistence farmers or people living off the land
Socio-economic impacts on community health and well-being	Loss of income and productivity
	Social disruption
	Diminished quality of life
	Increased costs to health care
	Health effects of mitigation technologies

Populations of pests and stray animals, such as dogs and cats, may also increase in the aftermath of disasters. Flies and other rapidly breeding insects may increase dramatically in numbers. All of these problems can impact on health and food safety. People may be tempted to eat drowned animals after floods, which carries a risk. Food is especially susceptible to contamination when it is stored and prepared out of doors or in damaged homes where windows and possibly even walls are no longer intact.

Fires or explosions may result in foodstuffs becoming contaminated with dangerous chemicals or microorganisms, as well as being damaged by water. Food may be damaged by smoke, chemicals used in fire fighting, or by other chemicals originating from the accidental release or improper use of insecticides and other toxic substances.

Disaster-affected people eating food from centralized kitchens that are not properly equipped or run are extremely vulnerable to outbreaks of food borne disease. The combination of environmental contamination and improper handling of food increases the risk of epidemics of diseases such as cholera and shigellosis. In emergencies and disasters, food safety authorities should review all stages of the food supply, from production, processing and manufacturing, transport, distribution, and sale, to preparation in food service and catering establishments and households. (WHO 2002, WHO 2005b).

4.9.2.3 Diseases associated with displaced persons

Following an extreme event, persons often have to be temporarily relocated into areas with little or no infrastructure to cope with the numbers involved (WHO 2002). Large-scale population movements into an area are of primary concern for health. Such movements involve settlement on marginal land, usually away from services. Relocation can result in high population densities, associated with wholly inadequate water supplies and sanitation. There is almost always an increased risk of feacal–oral transmission of diseases related to poor hygiene. Diseases associated with displaced persons are listed in Table 7.

Other risks include contact of refugees with pathogens not found in the home area (e.g. the malarial parasite), including those transmitted by vectors unfamiliar to the evacuated population. Generally, the evacuated population will be more susceptible to these diseases than the local population, as occurs in areas endemic for malaria.

The relocation of a population into a high-density emergency settlement will usually greatly increase the risk of outbreaks of common childhood diseases. Measles is a particular risk when the population has low immunization coverage. Health conditions and nutritional status before displacement are also important. Evacuation can also place people in the vicinity of unfamiliar environmental hazards (e.g. dispersal of refugees into damaged industrial areas where toxic substances are stored). Even if the disaster did not strike the area that a particular local authority has jurisdiction over, the large-scale influx of displaced persons fleeing a distant disaster area can create a second emergency for a previously unaffected local authority. Few health services and local authority services can at short notice provide emergency housing, water and sanitation and food for a large-scale influx of displaced people.

4.9.3 Air pollution related health effects

Current exposures to air pollution have serious public health consequences. Ground-level ozone can exacerbate respiratory diseases and cause short-term reductions in lung function. Exposure to particulate matter can aggravate existing respiratory and cardiovascular diseases, alter the body's defense systems against foreign materials, damage lung tissue, and lead to premature death and possibly contribute to cancer. Health effects of exposure to carbon monoxide, sulfur dioxide and nitrogen dioxide can include reduced work capacity, aggravation of existing cardiovascular diseases, effects on breathing, respiratory illnesses, lung irritation and alterations in the lung’s defense systems.

The mechanisms by which climate change affects exposures to air pollutants include:

1. Affecting weather and thereby local and regional pollution concentrations
2. Affecting human-caused emissions, including adaptive responses involving increased fuel combustion for power generation
3. Affecting natural sources of air pollutant emissions
4. Changing the distribution and types of airborne allergens

Table 7: Biological hazards affecting displaced populations during disaster (WHO 2002)

Disease	**Symptoms**	**Environ-mental risk factors**	**Health hazards**
Acute upper respiratory tract infections	All symptoms of the common cold, fever and heavy coughing. Chest pain and pain between shoulder blades in pneumonia	Crowding, poor hygiene	Influenza and pneumonia may cause severe complications, especially in groups at risk
Diarrhoea	Watery stools at least three times a day, with or without blood or slime. May be accompanied by fever, nausea or vomiting.	Contaminated drinking-water or food, or poor sanitation	Dehydration, especially in children, shown by dark coloration of urine, dry tongue or leathery skin. Severe risk to immune-compromised persons
Measles	A disease of early childhood, characterized by fever and catarrhal symptoms, followed by skin eruption and maculopapular rash in the mouth.	Crowding, poor hygiene	Severe constitutional symptoms, high case fatality rate
Malaria	Painful muscles and joints, high fever with chills, headache, possibly diarrhoea and vomiting.	Breeding of *Anopheles* mosquitoes in stagnant water bodies.	Disease may rapidly become fatal, unless medical care is provided within the first 48 hours.
Meningococcal meningitis	Infected persons may show no symptoms for a considerable time. When an epidemic is in progress, headache, fever and general malaise will suggest the diagnosis, which must be confirmed by lumbar puncture.	Crowding.	Often fatal if untreated at an early stage; neurological problems in survivors
Shigella dysentery	Diarrhoea with blood in the stools, fever, vomiting and abdominal cramps.	Contaminated drinking-water or food, or poor sanitation, poor hygiene	Case fatality rate may be high
Viral hepatitis A	Nausea, slight fever, pale-coloured stools, dark-coloured urine, jaundiced eye whites and skin after several days.	Poor hygiene	Long-term disabling effects
Louse borne typhus	Prolonged fever, headache, body pains	Unhygienic conditions leading to lice infestations	May be fatal without treatment
Typhoid fever	Starts off like malaria, sometimes with diarrhoea, prolonged fever, occasionally with delirium.	As for diarrhoea	Without appropriate medical care, may lead to fatal complications in a few weeks

Disease	Symptoms	Environ-mental risk factors	Health hazards
Cholera	Modest fever, severe, but liquid diarrhoea (rice water stools), abdominal spasms, vomiting, rapid weight loss and dehydration.	As for diarrhoea	As for diarrhoea
Diphtheria	Inflamed and painful throat, coughing.	Crowding, poor hygiene	A secretion is deposited in the respiratory tract, which can lead to asphyxiation.
Rabies	Fatigue, headache, disorientation, paralysis, hyperactivity.	Bite from infected animal host	Very high fatality rate.

Analyses show that higher surface air temperatures are conducive to increased concentrations of ground-level ozone. Since it is very likely that temperatures will increase significantly by the end of the 21st century, this creates a risk of higher concentrations of ground-level ozone, especially because higher temperatures are frequently accompanied by stagnating circulation patterns. However, without knowledge of future emissions in specific places, the success of air pollution policies, and local and regional meteorological scenarios, more specific predictions of exposure to air pollutants and health effects cannot be made with confidence.

In addition to affecting exposure to air pollutants, there is some chance that climate change will play a role in exposure to airborne allergens. Climate change will possibly alter pollen production in some plants and the geographic distribution of plant species. Consequently, there is some chance that climate change will affect the timing or duration of seasonal allergies. The impact of pollen and of pollen changes on the occurrence and severity of asthma, the most common chronic respiratory disease of childhood, is currently very uncertain.

4.9.4 Water borne and food-borne diseases

Many infectious diseases are sensitive to either temperature or rainfall, showing strong seasonal variation in numerous sites. Many diarrhoeal diseases (infectious intestinal disease) peak in cases during the hottest months of the year. This is true for *Salmonella* infections in Europe and for *Shigella* infections in South Asia. Temperature and relative humidity directly influence the rate of replication of bacterial and protozoan pathogens and the survival of enteroviruses in the environment. Rainfall, and especially heavy rainfall events, may affect the frequency and level of contamination of drinking-water.

Diarrhoeal diseases have multiple modes of transmission, such as via water, food, insects or contact between humans. The relative importance of the various pathogens that cause diarrhoea varies between locations and is greatly influenced by the level of sanitation. Several studies have described climate effects on specific diarrhoea pathogens (Campbell-Lendrum et al 2003). Pathogens vary in the severity of clinical symptoms and the likelihood that they will be reported to health services. The numbers of cases reported either through clinics or laboratory-based surveillance therefore only represents a small proportion of the total disease burden, especially for diseases that are not severe. Further, relationships between climate and disease derived from passive reporting may differ from those based on other methods of surveillance.

Climate change could greatly influence water resources and sanitation in situations where water supply is effectively reduced. Drought events can lead to an increased concentration of pathogenic organisms in raw water supplies. In addition, water scarcity may necessitate using sources of fresh water of poorer quality, such as rivers, which are often contaminated. Increases in rainfall may cause flooding and overwhelm sewerage systems. All these factors could result in an increased incidence of disease.

Exposure to water-borne disease can result from drinking contaminated water, eating seafood from contaminated water, eating fresh produce irrigated or processed with contaminated water, or from activities such as fishing or swimming in contaminated water. Water-borne pathogens of current concern include viruses, bacteria, and protozoa (such as *Cryptosporidium*, associated with gastrointestinal illnesses). Changes in precipitation, temperature, humidity, salinity, and wind have a measurable effect on water quality. In 1993, the Milwaukee, Wisconsin drinking water supply became contaminated by *Cryptosporidium*, and as a result 400 000 people became ill. Of the 54 individuals who died, most had compromised immune systems because of HIV infection or other illness. A contributing factor in the contamination, in addition to treatment system malfunctions, was heavy rainfall and runoff that resulted in a decline in the quality of raw surface water arriving at the Milwaukee drinking water purification works.

In Florida, during the strong El Niño winter of 1997-1998, heavy precipitation and runoff greatly elevated the counts of faecal bacteria and infectious viruses in local coastal waters. In Gulf Coast waters, *Vibrio vulnificus* bacteria are especially sensitive to water temperature, which dictates their seasonality and geographic distribution. In addition, toxic red tides proliferate as seawater temperatures increase. Reports of marine-related illnesses have risen over the past two and a half decades along the East Coast in correlation with El Niño events.

Climate changes projected to occur in the next several decades, in particular the likely increase in extreme precipitation events will probably raise the risk of contamination events.

4.9.5 Vector-borne diseases

Humans may become infected with the pathogens that cause diseases through transmission by insects or ticks (such as Lyme disease, which is tick-borne) or by direct contact with the host animals or their body fluids (such as hantaviruses, which are carried by numerous rodent species and transmitted to humans through contact with rodent urine, droppings and saliva). The organisms/animals that directly transmit these diseases are known as vectors. The ecology and transmission dynamics of these vector-borne infections are complex and the factors that influence transmission are unique for each pathogen. (Lindgren and Gustafson 2001)

Vector organisms that do not regulate their internal temperatures and are therefore sensitive to external temperature and humidity transmit many important infectious diseases. Climate change may alter the distribution of vector species (increasing or decreasing) depending on whether conditions are favourable or unfavourable for their breeding places (such as vegetation, host or water availability) and their reproductive cycle. Temperature can also influence the reproduction and maturation rate of the infective agent within the vector organism and the survival rate of the vector organism, thereby further influencing disease transmission.

Climate affects a variety of biological processes in vectors, influencing their presence or absence at a particular time and place, their abundance and their ability to transmit disease. These aspects are best described for anthroponotic diseases such as malaria. The overall ability of a vector population to transmit disease can be summarized as the 'vectorial capacity'. Vectorial capacity has various formulations (Garret-Jones 1964, Dye 1992), but is a function of the following parameters:

- Human-biting rate (the daily biting rate of a female mosquito)
- Human susceptibility (the efficiency with which an infective mosquito infects a human)

- Mosquito susceptibility (the chance that an uninfected mosquito acquires infection from biting an infectious person)
- The probability of daily survival of the mosquito
- The incubation period for the parasite inside the mosquito

Changes in climate that can affect the potential transmission of vector-borne infectious diseases include temperature, humidity, altered rainfall, soil moisture and rising sea level. Determining how these factors may affect the risk of vector-borne diseases is complex. The factors responsible for determining the incidence and geographical distribution of vector-borne diseases are complex and involve many demographic and societal as well as climatic factors. Transmission requires that the reservoir host, a competent vector and the pathogen be present in an area at the same time and in adequate numbers to maintain transmission.

Malaria, yellow fever, dengue fever, and other diseases transmitted between humans by blood-feeding insects, ticks and mites were once common in the USA. (Ebi et al 2006) Many of these diseases are no longer present, mainly because of changes in land use, agricultural methods, residential patterns, human behavior and vector control. However, diseases that may be transmitted to humans from wild animals continue to circulate in nature in many parts of the country. This distribution pattern can change dramatically during disaster situations or gradually as climate changes take effect. The present situation regarding these vector-borne diseases in the USA and its capacity to change for the worse under climate change scenarios is an example that applies to much of the rest of the world as well.

Most vector-borne diseases exhibit a distinct seasonal pattern, which clearly suggests that they are weather sensitive. Rainfall, temperature and other weather variables affect both vectors and the pathogens they transmit in many ways. For example, epidemics of malaria are associated with rainy periods in some parts of the world, but with drought in others. Higher temperatures may increase or reduce vector survival rate, depending on each specific vector, its behavior, ecology, and many other factors. In some cases, specific weather patterns over several seasons appear to be associated with increased transmission rates. For example, in the Midwestern US, outbreaks of St. Louis encephalitis (a viral infection of birds that can also infect and cause disease in humans) appear to be associated with the sequence of warm, wet winters, cold springs and hot dry summers. (Ebi et al 2006) The factors underlying this association are complex and require more investigation.

4.9.6 Effects of food and water shortages

Food security remains one of the main political concerns of climate change. High seasonal and year-to-year variability in food supplies, often the result of unreliable rainfall and insufficient water for crop and livestock production, is a major contributor to chronic undernutrition and food insecurity. Drought affects health through several pathways. In the most extreme case, famine, the number of deaths associated with insufficient food consumption increases substantially. Famine often occurs when a pre-existing situation of malnutrition worsens. Although food yields and agriculture has been a main focus of research on the impact of climate change, surprisingly little work has been done on how climate change may affect health through changes in the food supply.

The IPCC Third Assessment Report (IPCC 2001) was reasonably optimistic that, at the global level, the agricultural system could adapt to climate change in the near term. However, the distribution of vulnerability among regions and populations will be uneven. For example, in some tropical areas, crops are already near their maximum temperature tolerance. In dry-land areas, non-irrigated agricultural production is likely to be sensitive to even small changes in precipitation. Poor people, and especially those living in marginal environments, are most vulnerable to climate-induced food insecurity (Downing and Parry 1994).

Hunger and malnutrition are already among the most devastating problems facing countries. United Nations Food and Agricultural Organization (FAO 2002) estimated that 840 million people were undernourished in 1998–2000. This figure includes 11 million in industrialized countries, 30 million in countries in transition and 799 million in developing countries. This latest figure of 799 million represents a decrease of only 20 million since 1990–1992, the benchmark period used at the World Food Summit. Nearly half the people in countries in Central, Southern and Eastern Africa are undernourished. Environmental factors, both natural and those resulting from human activities, can limit agricultural potential. These include extremely dry or cold climate, poor soil, erratic rainfall, steep slopes and severe land degradation. The FAO (FAO 2002) further states that under-nutrition and malnutrition prevail in regions where environmental economic and other factors expose the population to a high risk of impoverishment and food insecurity. Countries that currently have problems with food security would be especially vulnerable to the potential impact of climate change on food supplies.

4.9.7 Mental health effects

There is controversy about the incidence and continuation of significant mental problems, such as post traumatic stress disorder, following disasters. However, a rise in mental disorders has been observed following several natural disasters in the US. There is much less known about the mental health impact of slow disasters such as persistent drought and the community destruction ensuing in its wake.

Disasters are events that challenge the individual's ability to adapt, which carries the risk of adverse mental health outcomes, including serious post-traumatic psychopathologies (Davidson and McFarlane 2006). The unique vulnerabilities of special populations within the affected community play an important role in determining the nature and amount of mental health morbidity. Disasters in developing countries and those associated with substantial community destruction are associated with a worse outcome (Davidson and McFarlane 2006).

Although acute responses are ubiquitous, few disasters lead to post-traumatic psychopathology in the majority of people exposed (Davidson and McFarlane 2006). However, the shortage of human resources in psychiatry, particularly in developing countries, places a considerable burden on psychiatric services, even without the additional constraints imposed by a disaster. Hence, disasters are events that invite a public health response to mental health that can better serve the needs of the individual and the affected community (Davidson and McFarlane 2006, Gard and Ruzek 2006). The experience in Myanmar after the Asian tsunami disaster showed that psychosocial and mental health support to the affected community not only reduced psychological distress but also facilitated physical rehabilitation (Htay 2006). Recent reports in the British media following the devastating July 2007 floods quoted public health officials saying that the biggest health associated with the floods is ‘overwhelming from mental stress’ (News24, 62/07/2007).

The IPCC (1991) noted that “the greatest effect of climate change may be on human migration as millions of people will be displaced due to shoreline erosion, coastal flooding and agricultural disruption”. Refugees represent a very vulnerable population with significant health problems. These problems include a disproportionate number of persons experiencing mental health problems, either temporarily or permanently. There is concern not only about the source of displaced people, but also about countries that may receive the displaced people.

4.9.8 Vulnerable subpopulations or groups in developing countries

The bulk of the world's population lives in rural areas (Rudel 1991). They are already faced with critical problems in the relationships between population numbers and the environment, such as tropical deforestation, desertification and land degradation (particularly in resource-poor areas). Agricultural development has been uneven in the past decades and many rural, subsistence-based populations have suffered a decline in standards of living, particularly in Africa (Rudel 1991, Mhalu 2005).

Farming is both affected by and has an impact on local and global environmental ecosystems. Trends that affect the environment and farming activities, directly affect the health of rural agricultural populations, especially in the developing world (Graber et al 2005). Although food production appears to have kept pace with population growth in macro statistics, 35% of the population in Sub-Saharan Africa, 22% of the Asian population and 22% of developing market economies were already estimated to be malnourished in the last decade of the 20th century (Graber et al 2005).

In developing countries, all efforts at development as well as reclamation of degraded areas, pollution reduction and preservation of biodiversity affect women's environment, especially in rural areas (Davidson 1993). Women produce most subsistence foods and cash crops, but control only about 1% of the world's land. Lack of land tenure and of access to land, keep women from obtaining credit and accessing training and other supports, thereby preventing them from using traditional long-term conservation practices (Davidson 1993). For example, in many developing countries, commercial producers force women off the most productive lands and onto marginal lands where they have to grow subsistence crops. They tend to overuse the marginal land and to allow little time for soil recovery. Soil degradation is exacerbated when women need to travel great distances to collect firewood, water, fodder and food. Even though women supply important water needs to their families and crops, they tend to be excluded from planning, implementing and maintaining water supplies. Deforestation and desertification tend to greatly increase these women's work burdens (Davidson 1993).

Poor women who have migrated to urban areas also experience environmental degradation, deteriorating health and resource depletion (Davidson 1993). Most live in informal settlements under deteriorating sanitation and declining economic circumstances. Rapid population growth, lack of support mechanisms and civil conflict are underlying factors that are already adversely affecting the huge but largely unacknowledged female work force in developing countries. Climate change will hit these women especially hard and official planning bodies should take their needs on board as a high priority.

4.10 References for Chapter 4

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CHAPTER 5

Case study: Cape Winelands District Municipality

5.1 Introducing the study area

In order to apply the current data on climate variability and change as well as the present approach regarding hazards and disasters to a particular study area, the Cape Winelands District Municipality was chosen as a case study. To fully understand the risks under a future climate scenario, it is necessary to assess the current risks (Kovats et al 2003). The existing hazards and risks will be assessed in this chapter, based on the methodology developed by Botha and Louw (2004) discussed in the chapter 3.

5.1.1 Geography

The Cape Winelands District Municipality is one of the five district municipalities comprising the Western Cape Province of South Africa, located at the south-western tip of Africa, bordering the metropolitan area of the City of Cape Town on its west. The district extends over a total area of 22 289 km^2 and is subdivided into five local municipalities and a sixth area managed by the district in the north of 12 000 km^2.

The five municipalities are:

- Breede River/Winelands – consisting of Ashton, Bonnievale, McGregor, Montagu and Robertson urban areas and rural surrounds,
- Breede Valley – consisting of De Doorns, Rawsonville, Touws River and Worcester urban areas and rural surrounds,
- Drakenstein – consisting of Gouda, Paarl, Saron and Wellington urban areas and rural surrounds,
- Stellenbosch – consisting of Franschhoek, Klapmuts, Pniel and Stellenbosch urban areas and rural surrounds,
- Witzenberg – consisting of Ceres, Op die Berg, Prince Alfred's Hamlet, Tulbagh and Wolseley urban areas and rural surrounds.

The Cape Winelands District is dominated by the mountains of the Cape Fold Belt, dividing the area in two, with the low-lying Drakenstein and Stellenbosch located on the western side, and higher altitudes to the east, as illustrated in Figure 13. Although the area has an Mediterranean style climate with cool wet winters and warm summers, the higher altitude mountains also experience some summer precipitation. The average annual rainfall for the district varies between amounts of higher than 2 000 mm in the mountains to less than 250 mm in the north-eastern district management area. The mountain catchments are the main source of the district's, as well as the Cape Metropole's, water supply.

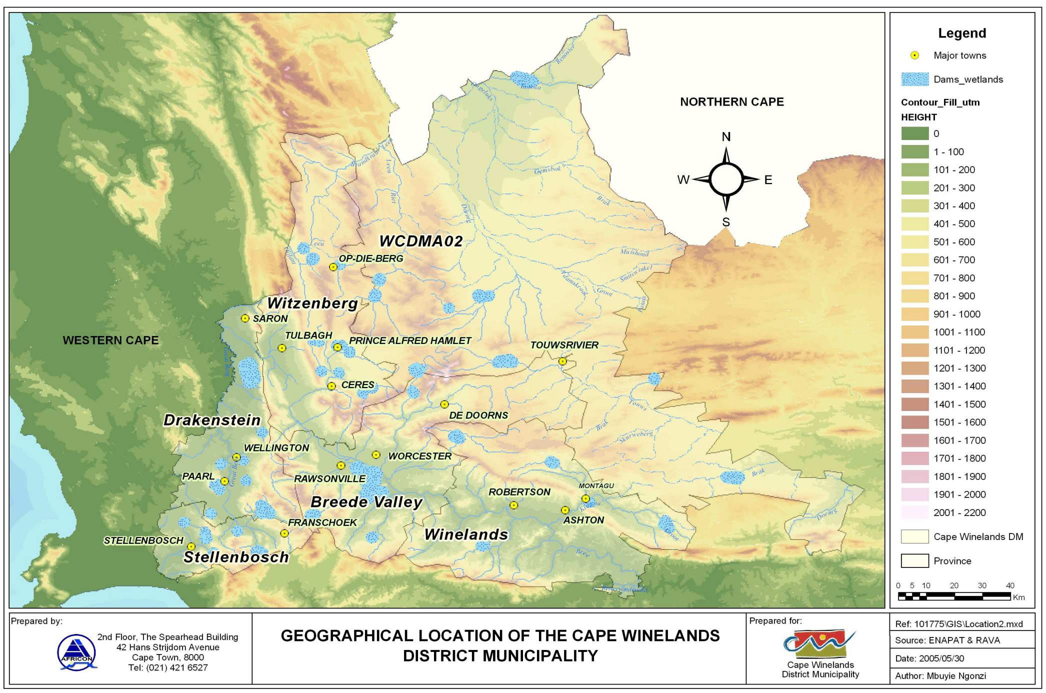

Figure 13: The Cape Winelands District Municipality

5.1.2 Population

The total population of the district is 629 490 (Census 2001 from Statistics South Africa 2007) inhabitants. The location per municipality and the age distribution is shown in Table 8 and Table 9.

Table 8 shows a larger female population in all municipalities, except for the district managed area, with 30% of the total population living in the Drakenstein local municipality, indicating a smaller rural population and a possible migration towards larger towns on the metropolitan fringe.

Table 8: Population per local municipality for the Cape Winelands District Municipality (Census 2001 from Statistics South Africa 2007)

	Male	Female	Total
WC022: Witzenberg	41519	42054	83573
WC023: Drakenstein	95227	99188	194415
WC024: Stellenbosch	57068	60634	117703
WC025: Breede Valley	71513	74517	146030
WC026: Breede River/Winelands	39308	41962	81270
WCDMA02:	3439	3060	6499
	308074	321415	629490

Table 9: Age distribution per gender for the Cape Winelands District Municipality (Census 2001 from Statistics South Africa 2007)

	Male	Female
0 - 4	29779	29450
5-9	30501	29962
10-14	30961	30542
15 - 19	32184	33073
20 - 24	29724	30292
25 - 29	27817	28655
30 - 34	26619	28261
35 - 39	24002	25214
40 - 44	19888	21822
45 - 49	15779	17048
50 - 54	12735	12960
55 - 59	9165	9788
60 - 64	7202	8208
65 - 69	5147	6059
70 - 74	3529	4495
75 - 79	1933	2916
80 - 84	1023	1883
85+	545	1333

Table 9 illustrates a relative young population, with numbers increasing steadily in the first three categories and reaching a maximum in the 15-19 year old age category, thereafter decreasing steadily with age. The predicted but unverified population for 2005 were 669 449 (Statistics

South Africa 2007). This projection is based on annual population growth rates that show a decline from 1.25% in 2001/2002 to 1.17% in 2004/2005. The annual growth rate for 2005/2006 is estimated at 1.06% (Statistics South Africa 2007). The profile is typical of a developing country with high birth rates and relatively smaller older population. The life expectancy for the Western Cape was 60.8 years in 1996, the highest of the provinces. The national life expectancy was 57 years. The 2002 figure is 61.5, again the highest of the provinces (Health Systems Trust 2007). Life expectancy is, however, declining nationally. For 2006, national life expectancy at birth was estimated at 49 years for males and 53 years for females (Statistics South Africa 2007). The dependency ratio for the Western Cape has decreased from 52.4 in 1996 to 48 in 2006. (The age dependency ratio is measured by adding the number of persons below 15 years of age and of 65 and divide by the number of persons between 15 and 64 years old). The ratio is consistently lower than that for other provinces and the national figures of 64.4 and 58 respectively (Health Systems Trust 2007). This is possibly due to a smaller number of HIV/AIDS related deaths in the 15 to 65 year old age group compared to other provinces or an increase in the infant mortality rate which have increased in the Western Cape from 13.2% in 1990 to 56.5% in 2003. The national average for 2003 was 57.6%.

5.1.3 Economy

The Cape Winelands District Municipality is one of the major contributors to the economy of the Western Cape (CWDM 2005a). The District is dominated by the following six employment sectors:

- Agriculture/Forestry and fisheries
- Community, social and personal
- Manufacturing
- Wholesale and retail
- Financial, insurance, real estate and business
- Construction

These six sectors account for 83% of employment in the area, with Agriculture/Forestry dominating (Census 2001 from Statistics South Africa 2007).

The most important agricultural activities in the area are horticulture and poultry farming. Sixty-eight percent of the country's wine is produced in the district. The Western Cape is the country's largest producer of deciduous fruit, accounting for about 85% of exports. Twenty three percent of apples, 57% of pears and 66% of table grapes are produced in the Cape Winelands. Many of these activities – wines, table grapes, pears, apples and apricots - are export focussed. Water availability, high land prices, slow international markets and excess produce are, however, considered as constraints to entering the market which have contributed to the recent decline in farming activities and the selling of farms.

The manufacturing sector is characterised by its cross-linkages to the agricultural sector. Food manufacturing contributes to almost a third of all manufacturing and generates 56.45% of sales in the manufacturing industry (Census 2001 from Statistics South Africa 2007). It includes mostly production in the food and beverage sector such as wine, juice and juice concentrates, brandy and fruits (dried and tinned). These are mainly small to medium, well-established enterprises. Thirty-eight percent of the district's income is generated by the agricultural sector, which provides employment to more than 38.3% of the total labour force (Census 2001 from Statistics South Africa 2007).

The 2001 census statistics indicates an unemployment rate of 18% (unemployment is understood as a person earning no monthly income, excluding those that are not economically active). The figure is however misleading due to the high percentage of seasonal workers in the agricultural sector and related industries that are unemployed for the rest of the year, which is not included in this statistic. According to the 2001 census, 86% of the population earned less than R1 600 per month. A total of 543 742 persons in the area are therefore living in relative and seasonal poverty.

5.1.4 Pre-existing health profile

Internationally the top three leading causes of premature mortality are listed as ischemic heart disease, stroke and respiratory infections, with diarrhoeal diseases, perinatal disorders, TB and malaria listed amongst the top 10 (Timmreck 2002, WHO 2003). Chronic and lifestyle diseases such as heart disease and stroke were previously associated with developing nations, but are now also prevalent in developing countries, previously mostly affected by infectious diseases. Tuberculosis remains the biggest threat in terms of infectious disease, with an estimated 8.8 million new cases reported in 2005 of which 7.4 million were in Asia and sub-Saharan Africa (WHO 2007). The statistics for the study area reflects these trends to a certain extent, with the exception of homicide and a larger number of deaths due to traffic accidents. The top 10 leading causes of premature mortality for Cape Winelands East (CWDM excluding Drakenstein and Stellenbosch), as summarised by Groenewald (2006) are:

1. Tuberculosis (14%)
2. HIV/AIDS (12%)
3. Homicide (10%)
4. Road traffic deaths (6%)
5. Pneumonia (5%)
6. Chronic obstructive pulmonary disease (COPD) (4%)
7. Ischaemic heart disease (4%)
8. Low birth weight and Respiratory distress syndrome (RDS) (4%)
9. Stroke (3%)
10. Diarrhoea (3%)

Although the figures for Stellenbosch and Drakenstein are excluded from this summary, it can be assumed that the leading causes would be similar. This assumption is made based on the fact that the leading causes for the 3 municipalities included in this summary are very similar, with the top 4 causes staying constant. This should however by considered with some scepticism in Stellenbosch, as the municipality is home to approximately 25 000 thousand tertiary students (the University of Stellenbosch) for most parts of the year, changing the population profile. Nevertheless, the top four causes in the three municipalities account for 40% of all deaths. There are however large differences between males and females. HIV/AIDS accounts for a large proportion of deaths in young women, whereas young males die mostly of injuries and accidents. Deaths among older people are mostly due to non-communicable causes. The under 5 mortality rate (the number of children under 5 years who die in a year, per 1000 live births) for the Western Cape is the lowest of all the provinces. The under 5 mortality rate for the Western Cape has however increased steadily since 1998 from 13.2 to 56.5 in 2003, comparing to that of the Eastern Cape increasing from 80.5 to 91 (Health Systems Trust 2007). A similar trend can be expected for the district.

5.1.4.1 Focus on tuberculosis

Tuberculosis is the main cause of premature mortality in the Cape Winelands. The Western Cape experienced an increase in TB cases over the last few years, from 464 cases in 1998 to 988 cases in 2004 (Health Systems Trust 2007). The TB caseload per 100 000 population per local municipality is shown in Table 10.

It should be noted that TB prevalence harbours an unknown number of cases that are also HIV positive. Because of societal resistance to identifying HIV positivity, the TB diagnosis is often given preference as an official cause of death in persons who had both conditions at the time of death. This is an under-estimation of HIV/AIDS prevalence.

Table 10: Total TB caseload per local municipality (Groenewald 2006)

Municipality	Total TB caseload					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Witzenberg	1324	1227	1335	1607	1166	1452
Breede River/Winelands	826	882	977	1164	1010	1067
Breede Valley	2642	2439	2734	2445	2479	2486
Drakenstein	*	*	*	*	*	*
Stellenbosch	*	*	*	*	*	*

* data not available

The cure rate for 2005 per local municipality is shown in Table 11. These figures are well below the national target of 85%, but have shown an increase in the three municipalities of Cape Winelands East since 2001 (Groenewald 2006). Data for Stellenbosch and Drakenstein were not available. It is however still an alarming statistics seen in the light of the recent increase in multi drug resistant TB and extreme drug resistant TB. In the case of Stellenbosch for example (table above), the cure rate implies that 35.2% of cases are not cured and may be potential carriers of the new strains. This figure cumulates for each year implying a ever-increasing problem if a 100% cure rate is not achieved.

Table 11: Cure Rate: New smear positive PTB per local municipality for 2004 (Groenewald 2006 and PGWC data)

Local Municipality	Cure rate %
Breede River	76.2
Breede Valley	60.1
Witzenberg	63.6
Drakenstein	72.0
Stellenbosch	64.8

5.1.4.2 Infant mortality

Infant mortality rate (or ratio) has in the past been widely used as an indicator of overall population health status. A high rate has been interpreted as an indication of a poorly functioning health system, poor accessibility to service, health and nutrition shortcomings and unfavourable environmental conditions. It has since been questioned (Murray 1988) and is now regarded as only one of the indicators of overall health. It is however an indication of maternal health and maternal education, which reflects a possible sub-standard health service. Indirect causes of infant deaths are non-medical conditions that make infants more vulnerable to direct causes of disease such as genetic diseases, birth trauma and infection. The major indirect causes of death are due to social, economic and environmental circumstances. (pers comm. Barnes 2007) In South Africa, the infant mortality rate (IMR) has declined from approximately 80 per 1 000 live births in 1980 to 50 per 1 000 live births in the 1990's. Infant mortality is calculated as:

IMR = Total deaths < 1 yr X 1 000 / total live births in a particular year

Since then it showed a steady increase to 59 per 1 000 live births, mainly due to HIV/AIDS (Groenewald 2006). The Western Cape IMR is the lowest in the country (31.7 per 1 000). Severe malnutrition figures (under 5 years incidence) also indicates the Western Cape as having the lowest figures, and steadily declining since 2001. The Cape Winelands has a similar rate to the Western Cape, and is stable since 1997. However, there is a variation between the municipalities. The IMP per local municipality is shown in Table 12.

Table 12: Infant Mortality Rate per local municipality (from Groenewald 2006)

Year	Witzenberg	Breede Valley	Breede River/ Winelands	Stellenbosch	Drakenstein
2001	47	31	38	No data	No data
2002	43	32	37	No data	No data
2003	44	24	31	No data	No data
2004	41	25	37	No data	No data
2005	41	20	36	No data	No data

The IMR has declined steadily since 2001 in the three local municipalities listed, but has to be interpreted with caution due to data collection problems in some districts as well as a smaller number of births in some districts. Women in their childbearing years who are HIV positive, or who have TB or other diseases are often less fertile and when a significant proportion of the female population in that age group suffer from disease and malnutrition, the fertility rate drops. The leading cause of infant mortality is low birth weight (prematurity), followed by diarrhoeal disease, both expected due to the demographic profile of the area.

The socio-economic well-being of a community can inter alia be informally gauged by the proportion of babies of low birth weight born in a year. Low birth weight is defined as less than 2 500g weight at birth. Causative factors include poor health status of the mother, due to such deleterious factors as infections, substance use, smoking and genetic factors. The low birth weight rate for the Western Cape for 2006 was 16.6%, the second highest for a province in South Africa. Nationally the figure is 8.9%.

5.1.4.3 Diarrhoeal Disease

Diarrhoeal disease is the 4th biggest cause of death in the world following Ischaemic hart disease, stroke and respiratory infections, killing 5 to 8 million persons of all ages (Baysac and Beilstein 1997, Timmreck 2002). Along with acute respiratory infections, it is worldwide the leading cause of death for children under 5 years of age. In South Africa, diarrhoeal deaths are the primary cause of mortality in the under 5 year olds, estimated at 160 to 200 deaths per day (Medical Research Council 2007). It is closely related to socio-economic conditions, environmental health, the availability of clean water and sanitation (Barnes 2003, Cutler 2007, Oni 1996). Diarrhoea incidence in children under 5 years of age per 1 000 population is therefore used as an indicator of the health status of children and to identify potential environmental hazards such as the contamination of water sources. Nationally, the diarrhoea incidence in the under 5 year old category decreased from 286 per 1 000 population to 128 per 1 000 population in 2004. The figures for the Western Cape are 214 and 83 respectively. Diarrhoeal disease is the second highest cause of infant mortality in the Cape Winelands region. These figures are a cause for concern and indicate a significant portion of the population that is poverty-stricken and lacking knowledge concerning basic health issues. It can also serve as an indicator that a significant portion of the population live in polluted environments or are exposed to contaminated water and poor sanitation.

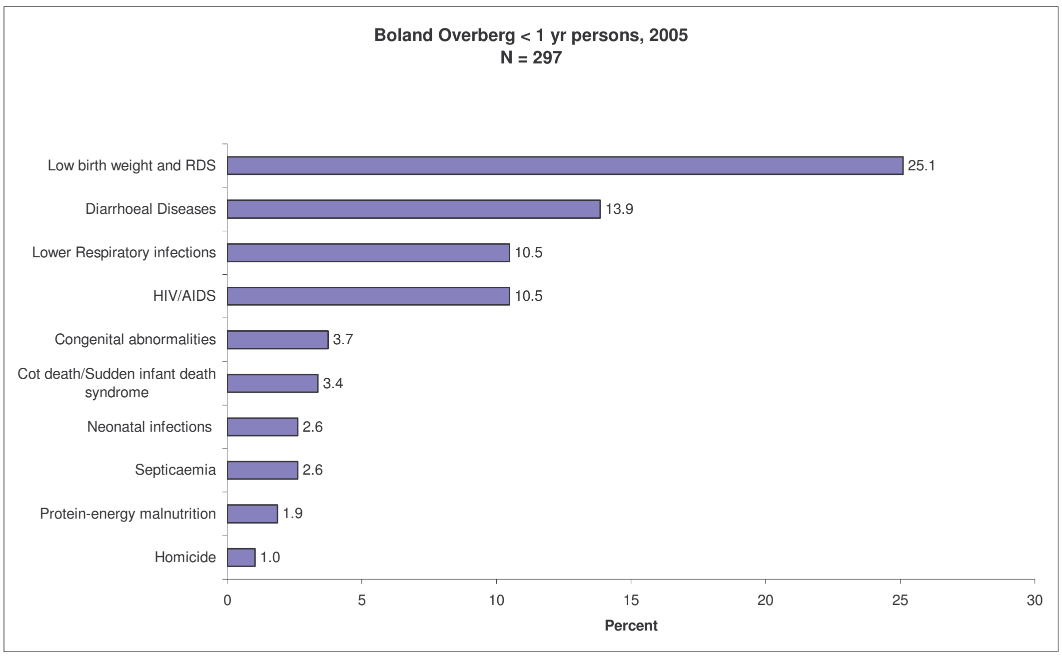

Figure 14: Leading causes of infant mortality (Groenewald 2006)

Groenewald (2006) attributes the relative high diarrhoeal incidence in children under 5 to under serviced communities such as farm workers and informal settlements. Children and the elderly are the most vulnerable population groups and a high diarrhoeal incidence is therefore an indication that other infectious disease may also pose a threat. It also indicates the possible existence of other gastro-intestinal disease causing organisms which may be linked to poor sanitation and water supply.

Different types of diarrhoeal disease, their pathogens and reservoir are summarised in Table 13.

Table 13: The pathogens associated with diarrhoeal disease (Levinson and Jawetz 1998)

Pathogen	Disease	Main reservoir
Escherichia coli variants (entero-adherent, entero-toxigenic, entero-invasive)	Diarrhoea	Contaminated water, food, poor sanitationHumans
Escherichia coli O157:H7 (enterohaemorrhagic)	Haemorrhagic colitis Bloody diarhrhoea and haemolytic-uremic syndrome	Cattle Undercooked meat, food, water
Salmonella enteridis and other Salmonella species	Food poisoning	Contaminated environment, food, water Domestic animals
Vibrio cholerae (not currently present in the CWDM)	Cholera	Various foods, water
Shigella spp	Dysentery	Various foods, water
Salmonella typhi	Typhoid	Humans, food, flies, water
Schistosomiasis mansoni (not currently present in the CWDM)	Bilharzia (also other symptoms)	Water infested by infected snails

The role of water as either the reservoir or transmission agent illustrates the importance of water quality and sanitation in disease control. In South Africa the proportion of the population with access to improved drinking water was respectively 99% in urban and 73% in rural areas for 2004 (WHO 2007). The figures for sanitation is however alarmingly smaller, with only 46% of people in rural areas and 79% of urban dweller having access to improved sanitation. Current statistics (April 2007) obtained from the Department of Water Affairs, indicate a backlog in improved water supply of 27% for the district, compared to the 76% backlog in 2001 (DWAF 2007b). This figure indicates the percentage of people with no access to improved formal water infrastructure as percentage of the total backlog. In terms of sanitation, the situation is worse. 881% of people (218% of households), (the needy population as % of the total estimated backlog) have no access to formal sanitation. The inadequate water and sanitation systems aggravate the circumstances of an already poor and under-serviced population, making them extremely vulnerable to disease.

5.1.4.4 State of present health service delivery in the Cape Winelands

In order to monitor the effectiveness of the health system of the district and its components, inputs into the health system, processes and outputs need to be measured (Barron et al 2006). These measurements in turn need to be related to changes in health outcomes as well as an assessment of their impact. This is not always possible due to lack of disaggregation of data below provincial levels.

Another obstacle is the lack of benchmarks or targets to evaluate the data (Barron et al 2006). For some indicators (e.g. immunization coverage of 90%; TB cure rate of 65%) there are clear and unambiguous targets. However for the majority of indicators, there are either an absence of targets or the targets are not based on the current realities of the health system (Barron et al 2006). In the absence of realistic targets, one can use the South African averages as a proxy for benchmarking district performance, but it must be kept in mind that this strategy has serious limitations.

The choice of indicators is important and such measurements should reflect the uptake and quality of the health services as well as the extent of the services. In this light the choice of indicators in the District Health Barometer (Barron et al 2006) are less than optimal. For instance, the average length of stay (ALOS) is taken as a proxy measure of the quality of care received as well as the efficiency of the hospital. The ALOS measures how long patients spend in district hospitals. It is calculated by dividing the number of patient days by the number of separations, which include transfers, discharges and deaths. District hospitals generally admit acute, relatively uncomplicated patients and the idea is to treat them and discharge them as soon as is possible. The guideline figure from the National DOH is and ALOS of 3.4 days for district hospitals. Measuring quality of hospital management in this manner has the effect that staff is tempted to discharge patients prematurely in order to cope with the demand for new admissions and the lack of staff. It is unfortunate that the clinical workload for nurses in the whole province is not reported.

There are other indicators that should also be incorporated in any assessment of the adequacy of health services in an area, such as the degree of understaffing, the number of staff vacancies in important occupational categories, the length of waiting lists for surgical procedures in the different hospital departments, the current state of essential equipment, the number of agency staff versus permanent staff in various occupational categories and the number of private companies managing different functions in the various hospitals. Data on these variables will give a much more reliable picture of the actual state of the health services in the district than those rather optimistic assessments reported in the District Health Barometer (Barron et al 2006). Unfortunately data on these important indicators are not available in the public arena.

A brief mention of the health services in the Western Cape serves to place the district data in context (Barron et al 2006). The Western Cape contains 10% of the country's population (4.7 million people), of which 90% live in an urban environment. It has the best socio-economic development of all the provinces. The per capita expenditure on primary health care is the highest in the country at R306 per person. The utilization rate of these facilities is on average 2.7 visits per person per year. Unfortunately, an important indicator and useful management tool, namely nurse clinical workload, could not be calculated because of lack of data. This demonstrates a lack of monitoring by management in this province, which is unacceptable (Barron et al 2006).

The province has generally performed well in the management of priority diseases, compared with the rest of the country according to the District Health Barometer (Barron et al., 2006). The TB cure rate of 70.1% is the highest in the country and ahead of the national target of 65%. All antenatal clients were tested for HIV and of these women, 12.7% tested positive. This is the lowest HIV prevalence in SA. This province has distributed the highest number of male condoms in the country (19.2 per male per year) which is far higher than the national target of 7 per male. This has probably impacted the incidence of sexually transmitted infections in the province, which is the lowest in the country (2.7%).

The immunization programme in the province has improved coverage over the last 3 years to 89.9%, in 2005. However the drop-out rate of 6.3% is the highest in the country. The hospital indicators show a remarkably steady average length of stay around 2.7 days. The bed utilization rate has increased over the past 3 years to 72.6% and is well above the South African average of 63.9%. These indicators point to relatively well managed district hospitals when compared with the country as a whole as reported in the District Health Barometer (Barron et al 2006).

Cape Winelands district is the second most populous district in the Western Cape. It has the third lowest deprivation index in South Africa (1.98) with most households having access to piped water. (Barron et al., 2006) Expenditure per capita for primary health care services in the district has hardly increased since 2001 and at R208 per capita is below the South African average. The primary health care utilization rate has remained constant at 2.4 visits per person since 2003. This indicator measures the average number of visits per person per year to a public health facility and is a proxy measure for both access to primary health care as well as community satisfaction with these services. The latter deduction is open to debate.

The Cape Winelands district currently faces challenges in terms of service delivery in rural areas, on farms and in fast-growing urban informal settlements (Groenewald 2006). Health care services are delivered through 53 fixed and 25 mobile clinics, 4 district hospitals and 2 regional hospitals and 2 specialized hospitals (Barron et al 2006). These facilities had 1 051 beds in total. There are 5 private hospitals in the district with 609 beds.

Nurse clinical workload, an important management indicator, was not monitored. The TB cure rate in 2004 remained at 65%, the lowest in the province, with a decline in the smear conversion rate to 54.6% (Barron et al 2006). Almost all HIV positive newborns and 68.6% of their mothers received nevirapine. While the distribution rate of condoms (6.4%) has increased, it is well below that of Cape Town as well as below the average for the country. The number of women who deliver in a health facility has fluctuated, but there has been a steady increase in the Caesarean section rate. Both the immunization coverage and drop-out rates are below the SA average.

Since 1 July 2004 the district health services have the responsibility for monitoring water quality, food quality, providing safe water and sanitation, housing conditions and health promotion (Groenewald 2006). They have identified 8 divisional priorities for 2005 to 2008. These are TB control, HIV/AIDS management, child health, women's health, community based services, chronic disease management, district hospitals and the district health system. Overall the region is relatively well resourced in comparison to other regions in South Africa, but health issues continue to be a priority and require a more comprehensive response by the District. As has been reported in previous sections of this Chapter, the general health of a large part of the population in the district, notably those in the poorer income categories, is a source of concern. Many of these patients do not have regular access to primary health care facilities as often as needed. If factors such a climate change or other disaster events impact on this situation, the district health services may not cope very well without outside assistance.

5.1.5 Disaster Risk Management in the district: general capacity to cope

This section gives a brief overview of the capacity to cope with events and the general ability to manage disaster risk in the district. This is not an in-depth review as the capacity to cope with, or manage a specific hazard, is assessed as part of the risk assessment in further sections. Specifics regarding preparedness and response plans form part of the disaster management plans of a district and is outside the scope of this project.

5.1.5.1 General response capacity

The fire brigade is the first line of response in fire and rescue incidents in the district (pers comm. Lategan 2007). The District Fire Services controls 5 fire stations and coordinates services situated in each local municipality. There are fire stations situated in Stellenbosch, Paarl, Worcester, Ceres and Robertson. They are assisted by an additional 11 municipal fire stations under the jurisdiction of the 5 local municipalities inter alia Stellenbosch and Franschoek in the Stellenbosch municipality; Paarl, Wellington and Saron in the Drakenstein municipality; Ceres in Witzenberg municipality; Worcester and De Doorns in Breede Valley and Robertson, Montagu and Ashton serving the Breede River/Winelands municipality (pers comm. Josias 2007).

Mutual aid agreements exist between the district and the local municipalities, as well as with some farmers who have been supplied with basic fire fighting equipment to assist in rural areas. The fire fighting capacity is also enhanced by Working on Fire, a government poverty alleviation program. Working on Fire fire-fighters however receive only basic training and is used on an *ad hoc* basis on request from the District Fire Services. Helicopters are on stand-by during the high risk season and are used in case of severe fires. This service is 50% subsidized by the national Fire Fighting Agency. In general the fire services are well equipped with very little budget constraints (pers comm. Josias 2007). Only a few posts are currently vacant. Better coordination of services will however enhance service delivery (pers comm. Minnies 2007).

Emergency medical and rescue services (EMS) are provided by the provincial government of the Western Cape and have dispatch units in every district. The EMS dispatch unit for the Cape Winelands is situated in Worcester and has 40 ambulances, 3 response vehicles and 5 rescue vehicles available in the eastern side of the district - that includes Witzenberg, Breede River/Winelands and Breede Valley local municipalities. Stellenbosch and Drakenstein municipalities are serviced by the metropolitan dispatch unit at Tygerberg Hospital in Parow, a suburb of Cape Town. In an emergency situation, additional provincial resources from other units can also used. In all, 200 ambulance patrols are servicing the province, including that of the neighbouring City of Cape Town metropolitan area (with a fleet of 70 ambulances) providing first assistance to the Cape Winelands. EMS service delivery has increased by 20% over the last financial year in the province. Response times have been more than halved, and time spent at hospitals to admit a patient decreased from an average of 90 minutes to 20 minutes. This increase in efficiency can be attributed to the use of information technology that amongst others uses vehicle tracking allowing for better deployment of the fleet, a sophisticated incident management system and in-ambulance software that enables pre-admittance diagnosis. The increase in efficiency enables the province to serve more patients without having to increase the staff and vehicle fleet at a much larger cost. The EMS in the province works in close collaboration with provincial disaster management, sharing premises at the provincial Disaster and Emergency Management Centre at Tygerberg Hospital in Parow (pers comm Botha 2007).

5.1.5.2 Disaster Management status quo

The Disaster Management Act (South Africa 2003) instructs that a district:

- ***must*** establish a Disaster Management Center and appoint a Head of Centre (sections 43, 44 and 45) specialising in disaster management issues and playing a coordinating role
- ***must*** establish and implement an Disaster Management Framework aimed at ensuring an integrated and uniform approach to disaster management (section 42)
- ***may*** establish a Disaster Management Advisory Forum which is a body consisting of relevant disaster management role-players in the district with a consultative and coordinationg role (section 51)
- ***must*** prepare disaster management plans (sections 52 and 53).

The district is one of the view municipal entities in South Africa currently complying with all legislation as instructed by the Disaster Management Act. Disaster management services in the district are coordinated by the District Disaster Management Centre. This is currently a ‘virtual centre’, situated at the district’s offices in Stellenbosch, as the Disaster Management Centre is nearing completion in Worcester. It has a current full-time staff of 4. The District is assisted by and works in conjunction with officials in the local municipalities. Currently (2007) disaster management in the local municipalities is either the responsibility of the fire chief or traffic chief. Only Stellenbosch municipality has created a disaster management post that will be filled on 1 August 2007. It is the opinion of the District’s head of Disaster Management, Mr Shaun Minnies, that the district and municipalities are severely understaffed and do not have the capacity to efficiently fulfil their functions as stipulated in the Disaster Management Act (pers comm Minnies 2007). A project was launched in 2007 to design a staff organogram for the Centre based on the roles and responsibilities stipulated in the Disaster Management Act. The candidate acted as special advisor on this project. An advisory forum has been established in 2004 and meets every semester to assist the Centre and coordinate activities in the district and with other departments. A Disaster Management Framework for the district was also completed in 2004 and is due to be updated in 2008 to ensure that it is aligned with the more recently published national and provincial frameworks. The completion of the risk assessment (this project, in 2005) was the first step towards the completion of disaster management plans. The results of the risk assessment were subsequently used to update the existing disaster management plans.

Although the district seems relatively well equipped in terms of staff and response services in comparison with many other areas of South Africa, there is always room for improvement. Amongst others, the role of the Disaster Management Centre is still misunderstood, and the perception exists that disaster management is synonymous with emergency response. The awareness of the importance of risk reduction has however increased, but buy-in from other departments, such as the department of health, must still be achieved. The role of the Centre in this context is discussed in Chapter 6.

5.2 Disaster Risk Assessment results

In order to assess future risks, it is necessary to understand the current risks (refer to general methodological approach in chapter 1). A disaster risk assessment was completed in 2005, based on the methodology developed by Botha and Louw (2004) as described in Chapter 2, of which the candidate was the project leader. The 2005 project report assessed all risks, but only that with specific reference to this study are quoted here. Therefore, except when indicated otherwise, all material in the following sections of this chapter are the findings of the 2005 project, and the interpretation of the candidate.

5.2.1 Step 1: Information collection

Information regarding known or possible hazards was collected as a desktop exercise by the project team, consisting of Geography and GIS professionals. Expert reports were commissioned where the project team lacked the appropriate knowledge to interpret the information. These reports will be referred to under the appropriate sections. GIS data were collected from the Cape Winelands District Municipality, the 5 Local Municipalities and the following national government Departments: the Department of Water Affairs and Forestry, the Surveyor General, the CSIR, the Department of Agriculture, the Department of Environmental Affairs, and the Council for Geoscience. Census 2001 data was also sourced from Statistics South Africa.

5.2.2 Step 2: Hazard Assessment

The methodology described in chapter 2 is based on a consultative process parallel to the information collection in step 5.2.1. Members of the District Disaster Management Advisory forum were invited by letter to attend a workshop that were be held on 10 March 2005 in Worcester (refer to Annexure A). The invitations were sent to 46 members of the advisory forum (refer to names and organisations in annexure).

The aim of the workshop was to introduce the project, to explain Disaster Management terminology and concepts and the expected inputs from role-players. Specific reference was made to the paradigm shift from response and recovery to risk reduction and mitigation. Twenty six members of the following organisations attended:

Cape Winelands District Municipality,
Provincial Government (directorate disaster management),
Department of Agriculture,
The Salvation Army,
Department of Internal Affairs,
Worcester Commando (South African National Defence Force),
Department of Transport,
Provincial traffic,
Correctional Services,
Fire Services,
Hamnet (radio operators),
Western Cape Nature Conservation Board and
Department of Education.

Hazard identification questionnaires and hazard incident lists were designed by Botha and Louw (2004) for assessing disaster risk in the public sphere across South Africa (Annexure B). The hazard identification uses the UNISDR Hazard Classification (UNISDR 2002) classification system for hazard type. An extensive set of possible hazards was listed under each category and the respondent was asked to simply tick the appropriate box if such a hazard occurred in the area. For each of these identified hazards, the respondent was asked to provide details (date, area, losses) of the event on the accompanying incident list. These questionnaires were handed out to a representative of each local municipality (5 in total), whom were asked to coordinate the completion thereof in their areas of jurisdiction over the next following weeks. Due to the varied nature of the possible hazards, different officials were envisaged to be involved, such as fire services, Emergency Medical Services and Traffic. One questionnaire per municipality was however requested and coordinated by Disaster Management officials. Assistance was offered in the form of telephonic assistance and/or local municipal workshops. On their request, a presentation was made to the Breede Valley stakeholders on 22 March 2005 in Worcester to further clarify definitions and to explain the process. The due date for completion was 15 April, but the last questionnaire was only received on 4 June 2005. The information provided in the incident lists were very vague and in most cases relied on memory and opinions of officials. A spreadsheet with major incidents was however received from the Breede River/Winelands District which listed some events for the whole district. Although disappointing, the lack of formal information of local incidents is not unusual for the South African District and/or Local municipal sphere. This data was however used in conjunction with the desktop information collection process.

Inputs were analysed using an Access database and captured in Geographic Information Systems using ArcGIS 8.3 where possible. Table 14 lists the variety of hazards as identified by the municipal participants across the study area. Earthquakes were listed based on the 1968 Tulbagh earthquake, but was not recognized as a hazard for other local municipalities. It must be emphasised that this process is firstly an attempt to obtain historic data for incidents from the various role-players, but secondly is a valuable tool in judging the perception of disaster risk of the officials. The emphasis is often on sudden-onset natural events and accidents, and neglects slow-onset disasters such as environmental degradation.

5.2.3 Step 3: Risk Profiling Assessment

Once the hazard assessment and primary impact mapping for the area were completed, a second set of questionnaires were distributed via mail to the Local Municipal coordinators to complete. The task was the quantification of total risk and the manageability of each. A simple tick-box method was used and each risk was scored using the classification system explained in Chapter 2. The results of the risk prioritisation, risk manageability and the relative risk priority are shown per local municipality in the following sections.

Table 14: Identified hazards for the Cape Winelands District Municipality

Natural Hazards	
Geological Hazards	
earthquake	
Hydro Meteorological Hazards	
drought	severe storm
flood	wind storm
fire	snow
Biological Hazards	
food poisoning	malaria
meningococcal meningitis	polio
rabies	tuberculosis
typhoid	HIV/AIDS
Technological Hazards	
dam failures	hazardous materials by road
hazardous installations	aircraft accidents
hazardous spills	road accidents
derailment	
Environmental Degradation	
air pollution	soil erosion
water pollution	domestic water pollution

5.2.3.1 Breede River

Table 15: Results of the risk analysis for the Breede River Local Municipality

Risk Prioritisation Table for Breede River Local Municpality

Hazard	Exposure	Severity	Probability	Actions Needed
Fires	Occasional	Moderate	Normal	Preparedness Planning
Floods	Occasional	Extreme	Likely	Risk Reduction Interventions anc
Rail Derailment	Continuous	Extreme	Normal	Urgent Risk Reduction Interventi

Risk Manageability Detail Table of Breede River Local Municipality

Hazard	Awareness	Legislative Framework	Early Warning Systems	Government Resources	Existing Risk Reduction Measures	Public Participation	Municipal Management Capabilities
Fires	Poor	Good	Poor	Poor	Poor	Modest	Good
Floods	Poor	Modest	Modest	Modest	Poor	Modest	Good
Rail Derailment	Poor	Poor	Poor	Poor	Poor	Modest	Poor

Relative Risk Priorities Table for Breede River Local Municpality

Hazard	Total Risk	Total Risk Manageability	Relative Risk Priority	Actions Needed
Fires	Tolerable	Modest	Safe	Preparedness Planning
Floods	Destructive	Modest	Tolerable	Risk Reduction Interventions and Preparedness
Rail Derailment	Destructive	Modest	Destructive	Urgent Risk Reduction Interventions

5.2.3.2 Breede Valley

Table 16: Results of the risk analysis for the Breede Valley Local Municipality

Risk Prioritisation Table for Breede Valley Local Municpality

Hazard	Exposure	Severity	Probability	Actions Needed
Drought	Seldom	Moderate	Normal	Preparedness Planning
Earthquakes	Occasional	Extreme	Normal	Risk Reduction Interventions and Preparedness Planning
Fires	Continuous	Extreme	Likely	Urgent Risk Reduction Interventions
Floods	Continuous	Extreme	Likely	Urgent Risk Reduction Interventions
Hail Storms	Seldom	Moderate	Normal	Preparedness Planning
Severe Storms	Continuous	Extreme	Likely	Urgent Risk Reduction Interventions
Food Poisoning	Occasional	Moderate	Normal	Preparedness Planning
Malaria	Seldom	Insignificant	Unlikely	Preparedness Planning
Measles	Occasional	Moderate	Normal	Preparedness Planning
Meningococcal Infections	Occasional	Moderate	Normal	Preparedness Planning
Polio	Seldom	Insignificant	Unlikely	Preparedness Planning
Tuberculosis	Continuous	Extreme	Likely	Risk Reduction Interventions and Preparedness Planning
Typhoid	Seldom	Moderate	Normal	Preparedness Planning
HIV/AIDS	Continuous	Extreme	Likely	Risk Reduction Interventions and Preparedness Planning
Dam Failures	Continuous	Extreme	Likely	Urgent Risk Reduction Interventions
Aircraft Accidents	Occasional	Extreme	Likely	Urgent Risk Reduction Interventions
Bus Accidents	Continuous	Extreme	Likely	Urgent Risk Reduction Interventions
Air Pollution	Seldom	Insignificant	Unlikely	Preparedness Planning

Risk Manageability Detail Table of Breede Valley Local Municipality

Hazard	Awareness	Legislative Framework	Early Warning Systems	Government Resources	Existing Risk Reduction Measures	Public Participation	Municipal Management Capabilities
Drought	Modest	Modest	Modest	Poor	Poor	Poor	Poor
Earthquakes	Poor	Poor	Modest	Poor	Modest	Poor	Poor
Fires	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Floods	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Hail Storms	Modest	Modest	Modest	Poor	Poor	Poor	Poor
Severe Storms	Modest	Modest	Modest	Poor	Poor	Poor	Poor
Food Poisoning	Modest	Good	Good	Good	Good	Modest	Good
Malaria	Good	Good	Good	Good	Good	Good	Good
Measles	Good	Good	Good	Good	Good	Modest	Good
Meningococcal Infections	Modest	Good	Good	Good	Good	Modest	Good
Polio	Good	Good	Good	Good	Good	Good	Good
Tuberculosis	Good	Good	Good	Good	Good	Good	Good
Typhoid	Modest	Good	Good	Good	Good	Good	Good
HIV/AIDS	Good	Good	Good	Good	Good	Modest	Modest
Dam Failures	Poor	Modest	Poor	Poor	Modest	Poor	Poor
Aircraft Accidents	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Bus Accidents	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Air Pollution	Good	Good	Good	Good	Good	Good	Good

Relative Risk Priorities Table for Breede Valley Local Municpality

Hazard	Total Risk	Total Risk Manageability	Relative Risk Priority	Actions Needed
Drought	Safe	Modest	Safe	Preparedness Planning
Earthquakes	Tolerable	Modest	Tolerable	Risk Reduction Interventions and Preparedness Plan
Fires	Destructive	Poor	Destructive	Urgent Risk Reduction Interventions
Floods	Destructive	Poor	Destructive	Urgent Risk Reduction Interventions
Hail Storms	Safe	Modest	Safe	Preparedness Planning
Severe Storms	Destructive	Modest	Destructive	Urgent Risk Reduction Interventions
Food Poisoning	Tolerable	High	Safe	Preparedness Planning
Malaria	Safe	High	Safe	Preparedness Planning
Measles	Tolerable	High	Safe	Preparedness Planning
Meningococcal Infections	Tolerable	High	Safe	Preparedness Planning
Polio	Safe	High	Safe	Preparedness Planning
Tuberculosis	Destructive	High	Tolerable	Risk Reduction Interventions and Preparedness Plan
Typhoid	Safe	High	Safe	Preparedness Planning
HIV/AIDS	Destructive	High	Tolerable	Risk Reduction Interventions and Preparedness Plan
Dam Failures	Destructive	Modest	Destructive	Urgent Risk Reduction Interventions
Aircraft Accidents	Destructive	Modest	Destructive	Urgent Risk Reduction Interventions
Bus Accidents	Destructive	Modest	Destructive	Urgent Risk Reduction Interventions
Air Pollution	Safe	High	Safe	Preparedness Planning

5.2.3.3 Drakenstein

Table 17: Results of the risk analysis for the Drakenstein Local Municipality

Risk Prioritisation Table for Drakenstein Local Municpality

Hazard	Exposure	Severity	Probability	Actions Needed
Fires	Continuous	Moderate	Likely	Risk Reduction Interventions and Preparedness Planning
Floods	Occasional	Moderate	Normal	Preparedness Planning
Measles	Continuous	Moderate	Normal	Preparedness Planning
Polio	Continuous	Moderate	Normal	Preparedness Planning
Tuberculosis	Continuous	Extreme	Likely	Risk Reduction Interventions and Preparedness Planning
HIV/AIDS	Continuous	Extreme	Likely	Risk Reduction Interventions and Preparedness Planning
Accidents by Road	Seldom	Moderate	Unlikely	Preparedness Planning
Hazardous Spill	Seldom	Moderate	Unlikely	Preparedness Planning
Air Pollution	Occasional	Moderate	Normal	Preparedness Planning

Risk Manageability Detail Table of Drakenstein Local Municipality

Hazard	Awareness	Legislative Framework	Early Warning Systems	Government Resources	Existing Risk Reduction Measures	Public Participation	Municipal Management Capabilities
Fires	Good	Modest	Poor	Modest	Modest	Poor	Modest
Floods	Modest	Poor	Poor	Modest	Modest	Poor	Modest
Measles	Good	Good	Good	Modest	Modest	Modest	Good
Polio	Modest	Modest	Modest	Modest	Modest	Modest	Modest
Tuberculosis	Good	Good	Modest	Modest	Modest	Modest	Modest
HIV/AIDS	Good	Good	Modest	Modest	Modest	Modest	Modest
Accidents by Road	Modest	Modest	Modest	Modest	Modest	Modest	Modest
Hazardous Spill	Modest	Modest	Modest	Modest	Modest	Modest	Modest
Air Pollution	Modest	Modest	Modest	Modest	Modest	Modest	Modest

Relative Risk Priorities Table for Drakenstein Local Municpality

Hazard	Total Risk	Total Risk Manageability	Relative Risk Priority	Actions Needed
Fires	Destructive	Modest	Tolerable	Risk Reduction Interventions and Preparedness
Floods	Tolerable	Modest	Safe	Preparedness Planning
Measles	Tolerable	High	Safe	Preparedness Planning
Polio	Tolerable	Modest	Safe	Preparedness Planning
Tuberculosis	Destructive	High	Tolerable	Risk Reduction Interventions and Preparedness
HIV/AIDS	Destructive	High	Tolerable	Risk Reduction Interventions and Preparedness
Accidents by Road	Safe	Modest	Safe	Preparedness Planning
Hazardous Spill	Safe	Modest	Safe	Preparedness Planning
Air Pollution	Tolerable	Modest	Safe	Preparedness Planning

5.2.3.4 Stellenbosch

Table 18: Results of the risk analysis for the Stellenbosch Local Municipality

Risk Prioritisation Table for Stellenbosch Local Municpality

Hazard	Exposure	Severity	Probability	Actions Needed
Fires	Occasional	Extreme	Likely	Preparedness Planning
Floods	Occasional	Moderate	Normal	Preparedness Planning
Rockfall	Seldom	Insignificant	Unlikely	Preparedness Planning
Dam Failures	Seldom	Insignificant	Unlikely	Preparedness Planning
Hazmat Acc by Road	Seldom	Insignificant	Unlikely	Preparedness Planning
Hazmat Acc by Rail	Seldom	Insignificant	Unlikely	Preparedness Planning
Air Accidents	Seldom	Insignificant	Unlikely	Preparedness Planning
Air Pollution	Occasional	Moderate	Normal	Preparedness Planning
Land Degradation	Occasional	Moderate	Normal	Preparedness Planning
Erosion	Occasional	Moderate	Normal	Preparedness Planning
Earthquakes	Seldom	Moderate	Normal	Preparedness Planning

Risk Manageability Detail Table of Stellenbosch Local Municipality

Hazard	Awareness	Legislative Framework	Early Warning Systems	Government Resources	Existing Risk Reduction Measures	Public Participation	Municipal Management Capabilities
Fires	Good	Good	Poor	Good	Good	Good	Good
Floods	Good	Good	Modest	Modest	Good	Modest	Good
Rockfall	Good	Modest	Poor	Modest	Modest	Modest	Good
Dam Failures	Good	Good	Modest	Modest	Modest	Modest	Modest
Hazmat Acc by Road	Good	Modest	Poor	Modest	Modest	Modest	Modest
Hazmat Acc by Rail	Modest	Modest	Poor	Modest	Modest	Poor	Modest
Air Accidents	Modest	Modest	Modest	Modest	Modest	Modest	Modest
Air Pollution	Good	Modest	Modest	Modest	Modest	Modest	Modest
Land Degradation	Good	Good	Poor	Modest	Modest	Poor	Modest
Erosion	Modest	Modest	Modest	Modest	Modest	Modest	Modest
Earthquakes	Good	Good	Poor	Modest	Modest	Good	Good

Relative Risk Priorities Table for Stellenbosch Local Municpality

Hazard	Total Risk	Total Risk Manageability	Relative Risk Priority	Actions Needed
Fires	Destructive	High	Safe	Preparedness Planning
Floods	Tolerable	High	Safe	Preparedness Planning
Rockfall	Safe	Modest	Safe	Preparedness Planning
Dam Failures	Safe	High	Safe	Preparedness Planning
Hazmat Acc by Road	Safe	Modest	Safe	Preparedness Planning
Hazmat Acc by Rail	Safe	Modest	Safe	Preparedness Planning
Air Accidents	Safe	Modest	Safe	Preparedness Planning
Air Pollution	Tolerable	Modest	Safe	Preparedness Planning
Land Degradation	Tolerable	Modest	Safe	Preparedness Planning
Erosion	Tolerable	Modest	Safe	Preparedness Planning
Earthquakes	Safe	High	Safe	Preparedness Planning

5.2.3.5 Witzenberg

Table 19: Results of the risk analysis for the Witzenberg Local Municipality

Risk Prioritisation Table for Witzenberg Local Municpality

Hazard	Exposure	Severity	Probability	Actions Needed
Drought	Occasional	Moderate	Normal	Preparedness Planning
Earthquake	Occasional	Moderate	Normal	Preparedness Planning
Fire	Occasional	Insignificant	Unlikely	Preparedness Planning
Flood	Seldom	Insignificant	Unlikely	Preparedness Planning
Severe Storm	Seldom	Insignificant	Unlikely	Preparedness Planning
Tuberculosis	Continuous	Moderate	Normal	Risk Reduction Interventions and Preparedr
HIV/AIDS	Continuous	Moderate	Normal	Risk Reduction Interventions and Preparedr
Hazmat Accidents by Roa	Seldom	Insignificant	Unlikely	Preparedness Planning
Air Pollution	Occasional	Insignificant	Unlikely	Preparedness Planning

Risk Manageability Detail Table of Witzenberg Local Municipality

Hazard	Awareness	Legislative Framework	Early Warning Systems	Government Resources	Existing Risk Reduction Measures	Public Participation	Municipal Management Capabilities
Drought	Poor	Modest	Modest	Poor	Poor	Poor	Poor
Earthquake	Modest	Poor	Poor	Poor	Poor	Poor	Poor
Fire	Modest	Modest	Poor	Poor	Modest	Poor	Poor
Flood	Poor	Poor	Modest	Poor	Poor	Poor	Poor
Severe Storm	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Tuberculosis	Poor	Poor	Poor	Modest	Poor	Poor	Modest
HIV/AIDS	Poor	Poor	Poor	Poor	Poor	Poor	Poor
Hazmat Accidents by Roads	Poor	Modest	Poor	Poor	Poor	Poor	Poor
Air Pollution	Poor	Poor	Poor	Poor	Poor	Poor	Poor

Relative Risk Priorities Table for Witzenberg Local Municipality

Hazard	Total Risk	Total Risk Manageability	Relative Risk Priority	Actions Needed
Drought	Tolerable	Modest	Safe	Preparedness Planning
Earthquake	Tolerable	Modest	Safe	Preparedness Planning
Fire	Safe	Modest	Safe	Preparedness Planning
Flood	Safe	Modest	Safe	Preparedness Planning
Severe Storm	Safe	Poor	Safe	Preparedness Planning
Tuberculosis	Tolerable	Modest	Tolerable	Risk Reduction Interventions and Preparedness
HIV/AIDS	Tolerable	Poor	Tolerable	Risk Reduction Interventions and Preparedness
Hazmat Accidents by Roac	Safe	Modest	Safe	Preparedness Planning
Air Pollution	Safe	Poor	Safe	Preparedness Planning

5.2.4 Risk Summary

The use of questionnaires was, as stated in the previous section, mainly an attempt to obtain historic incident information. It also relied heavily on the opinions of disaster management officials and their perception of a certain hazard and the risk it poses. Disaster management officials were from various backgrounds, but many have entered this field though previous or current involvement in public safety, traffic, fire services or the military. It is therefore of utmost importance to interpret these results with caution. An independent assessment (see 5.2.1) to verify issues or address gaps was therefore needed.

The respondents correctly perceived that fires, floods and drought were common hazards and high risks for the district area. Some discrepancies in the analysis were however disconcerting. Expert reports (Barnes 2003; Hartnady 2005) revealed that disease, environmental degradation and earthquake risk are major threats to the area, which are not regarded as such by the respondents.

Barnes (2003) revealed severe pollution levels of the Plankenbrug River, mainly caused by informal settlements along the river. Not only is this a (slow-onset) disaster in itself, but it can lead to several secondary disasters if left uncontrolled. This may point to a lack of understanding of the definition of a hazard, or the perception of the responsibility sphere of the official involved in the analysis. An earthquake risk was also a surprise finding for most of the role-players. Although not affected upon by climate, it can contribute to the vulnerability of the area and escalate the severity of other risks, leading to a complex disaster. Although animal diseases were identified by the project team as a risk, it was not regarded as such by the officials completing the questionnaires. It was however decided to include it in the original risk assessment report. The major risks, as reported in Louw (Louw EJM 2005) are discussed in the following sections**.**

5.2.5 Floods

The Eastern portion of the Cape Winelands District falls in the second highest flood risk zones (based on numbers of floods recorded; 28 in total) in the country, the Gourits Water Management Area. **(**http://www.dwaf.gov.za)(Figure 15).

Flood risk is also expressed as Regional Maximum Flood (RMF), an empirically established upper limit of flood peaks that can be reasonably expected at a given site, based on recordings since 1856 at more than 500 sites. RMF magnitude is expressed by the Francou-Rodier regional coefficient K, ranging between 0 and 6.5. The RMF for South Africa is illustrated in Figure 16.

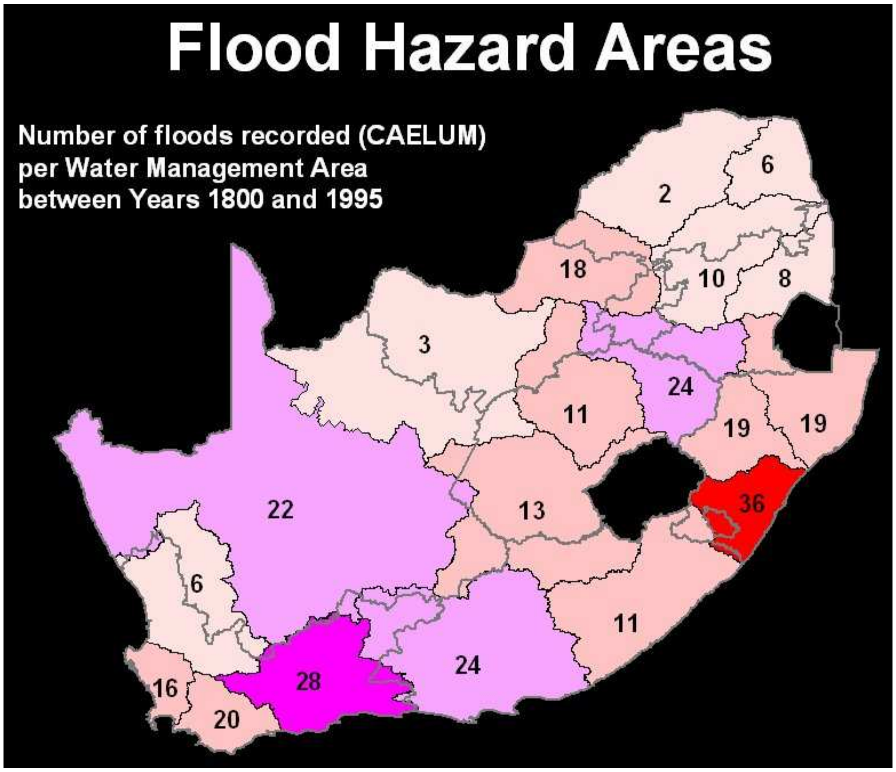

Figure 15: Flood Hazard Areas for South Africa (DWAF 2007a)

This figure illustrates a country with high flood risk, specifically in the southern and eastern coastal areas. The eastern parts of the Cape Winelands again fall in an area with the highest values for the Western half of the country.

Flooding is however also affected by local conditions such as the level of urbanisation, the soil type, the level of environmental degradation, the local storm water management and the drainage capacity. Major floods that occurred in the area were the Laingsburg floods of 1981, also affecting Montagu, Robertson and Ashton. It caused deaths, several injuries, loss of production, power failures and infrastructure damage and agricultural losses. Flash floods in De Doorns in 2002 resulted in the evacuation of 26 informal settlement houses, the collapse of 12 RDP (Reconstruction and Development Programme) houses and 1 death from drowning. The Montagu regional floods of 2003 caused serious disruption of schools and factories.

Two thousand five hundred people were evacuated from RDP houses and Cogmanskloof Pass was closed for 12 days - during harvesting season. The floods also resulted in the failure of the Bellair Dam, as well as bridges failing due to heavy rive flows, worsened by upstream debris. DiMP (2003) prepared a table that lists costs by organisation (see Table 20).

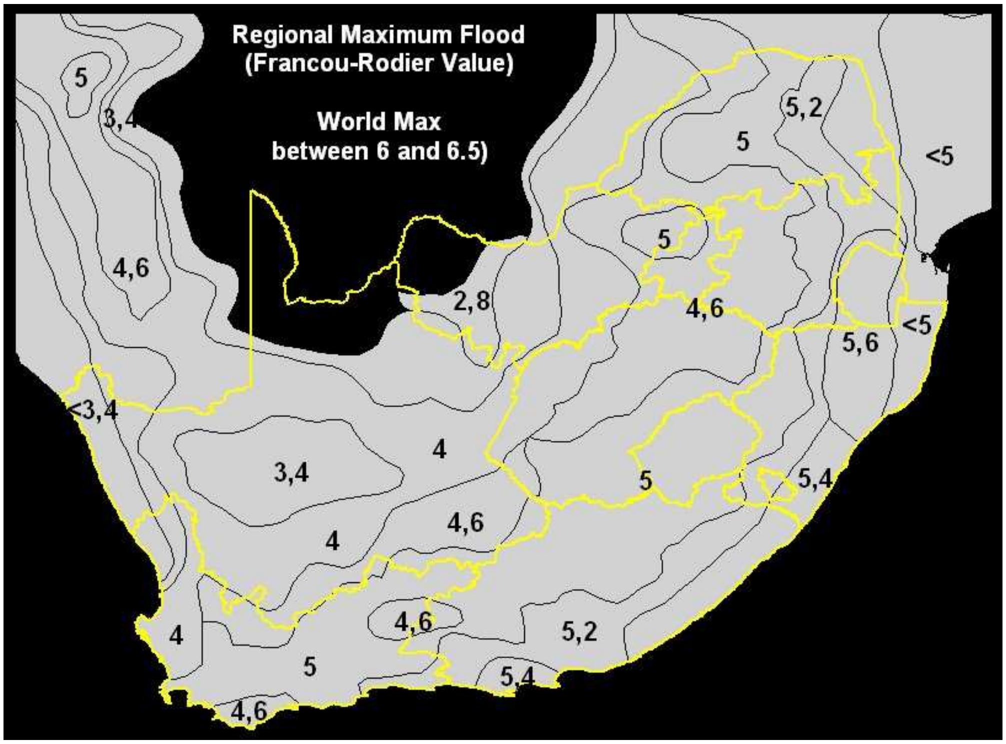

Figure 16: Regional Maximum Flood magnitude for South Africa (DWAF 2007a)

In retrospect, the weather systems preceding the Montagu floods spelt disaster to the informed analyst, but the communication and awareness structures were not in place to inform the farmers and authorities of the impending hazard.

Many communities have become more exposed to floods (Schulze 2003). Different pressures contribute to this, including shortage of land and migration of people to the endangered zones around cities and towns in the hope of overcoming poverty, such as the informal settlements in the Cape Winelands. Climate change, as discussed in the previous chapters, is predicted to increase the severity and extent of sudden-onset, severe events, such as floods. This will affect the poorest communities living in informal settlements the most, as it does currently. Already compromised immune deficiencies will result in higher incidences of waterborne disease, foodborne disease, infectious disease such as measles and respiratory infections. Diseases associated with sudden-onset flooding also include trauma injury as well as some mental health effects.

Table 20: Financial losses resulting from the 2003 flooding in the Montagu/Swellendam/Robertson magisterial Districts (DiMP 2003)

By Organisation / Administration	No. of Recorded Impacts	Losses (Rands)	% Total Loss
Dept. of Water Affairs and Forestry	48	13 850 000	6.52
Dept. of Agriculture	1	95 000	0.05
Dept. of Education	11	1 708 000	0.80
Nature Conservation (Dept. of Environmental Affairs and Tourism)	2	1 130 000	0.53
Emergency Services	n/a	100 000	0.05
Roads	139	78 584 200	36.99
District and Local Municipalities	36	6 921 827	3.26
Eskom	8	1 600 000	0.75
Agricultural land and infrastructure	716	89 521 136	42.14
Irrigation Boards	4	163 000	0.08
Private Insurance	91	3 201 500	1.51
Bellair Dam	1	14 000 000	6.59
National Dept of Social Development	774	1 548 000	0.73
Total	1831	212 422 663	100.00

Based on current risk of flooding and a probable increase in vulnerability due to socio-economic factors, flooding is seen as one of the major risks to the study area under a changed climate.

5.2.6 Fire

For the purposes of this study, fire was either classified as being a veld fire or a structural fire, the latter which includes informal settlement fires. Veld fires are regarded as the bigger threat by the District Fires Services (pers comm. Josias 2007) based on the number and severity of the recent incidents responded to. Most large fires, both veld and informal settlements) in the Western Cape are associated with southerly and south-easterly winds.

Van Wilgen (2000) states that "Veldfires in the Cape and other areas of South Africa are often caused by natural factors, such as lightning. Whatever the cause, however, veldfires are part of the natural ecological processes in most parts of the country. In many areas, large veld fires occur without necessarily posing a threat to life, property or the environment. In such cases, they are not real or potential disasters. However, more and more we have the situation where human settlement and development encroaches further into the natural environment, and veld fires therefore pose a growing threat to vulnerable properties and communities. In addition, environmental change such as the spread of alien invasive plants, a process that can be accelerated by fire, results in environmental hazard from veld fires. Thus overall the potential for disastrous veld fires grows." (End of quote.)

Weather conditions characteristic of high wildfire risk are persistent windy conditions coupled with high temperatures (>30° Celsius) and low mean relative humidity, most large wildfires in the Cape are associated with southerly or south-easterly winds.

On the basis of the effects of weather variables on natural present fueling, Van Wilgen (2000) identified five distinct fire climate zones or the Western Cape. These are:

- Western coastal zone: veld fires are not likely to occur under extreme conditions of high temperature, low relative humidity and high summer winds
- Western Cape inland zone north of Laingsburg including Hex River and Breede River valleys: high mean potential for fire in summer.
- South-western coastal zone: veld fires most likely under extreme conditions in summer and occasionally in winter under berg wind conditions.
- Eastern inland zone: potential peak in summer
- South-eastern coastal zone: veld fires under occasionally suitable conditions in either summer or winter: winter berg winds are important.

Many veld fires have resulted in significant financial losses and the occasional loss of life. Informal settlement fires are also a common phenomenon in the Western Cape and the Cape Winelands. Research has recently focussed extensively on the Cape Metropolitan Area to analyse seasonal patterns, frequency and severity (pers comm. G Fortune 2007), but very little data exist for the study area. Except for Stellenbosch local municipality, detailed incident lists for each municipality could not be obtained from the District Disaster Management officials or Fires Services.

The above illustrates that fires occur either during winter when fuel (in unsafe ways, such as small paraffin stoves that can be easily knocked over) is used for heating, or during the extended summer months when the area is dry and the south-easterly winds aggravates conditions. Densification does play a role in the severity of these events.

In summary, all informal settlements are high risk areas as a result of the close proximity of the dwellings to each other, the building materials used and the fuel used for lighting, cooking and heating. Industrial areas and areas on urban edge in close proximity of a plantation or veld, specifically fynbos, are also regarded as high risk.

A decrease in winter rainfall is predicted for the Western Cape under a changed climate. Drier conditions and storms, as well as an increased frequency of thunderstorms, points to a greater fire risk under natural conditions.

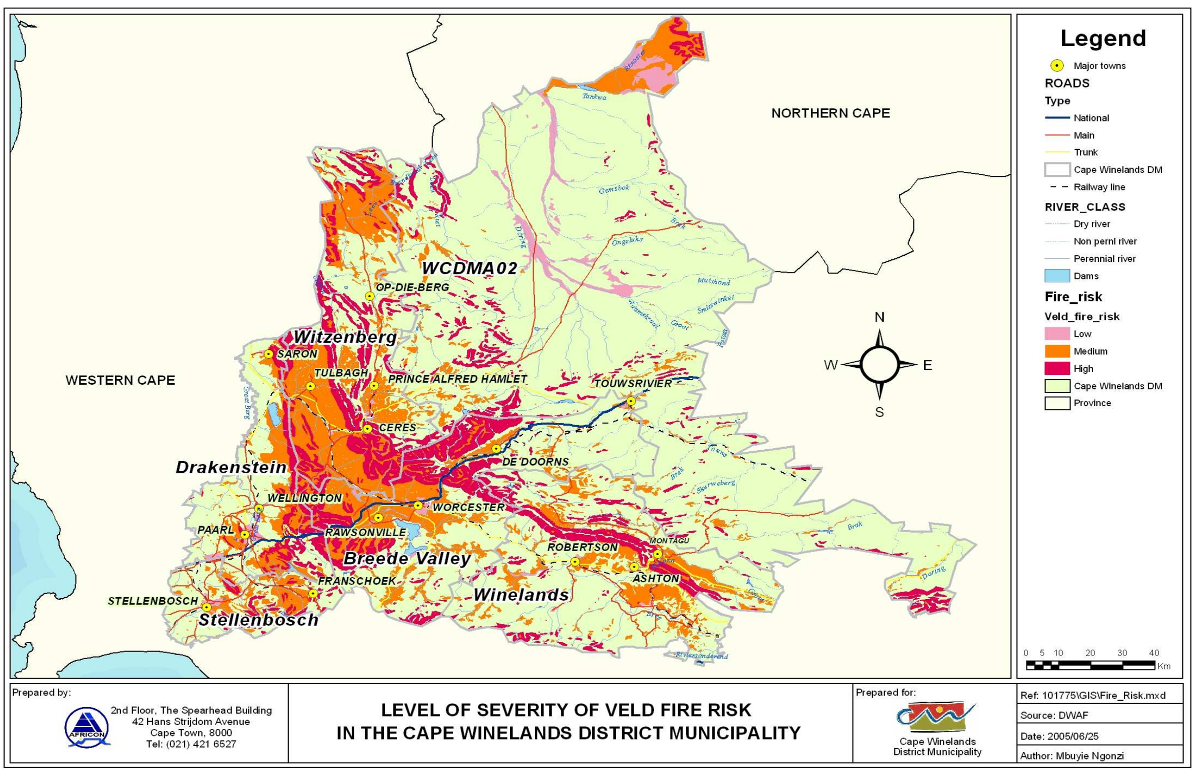

Figure 17: Veld fire risk

Table 21: Incident list of informal settlement fires in the Stellenbosch Local Municipality (Source: Cape Winelands Disaster Management Centre 2007)

Date	Area	Number of Shacks	Number of affected persons
09/02/04	Franschhoek	40	97
28/02/04	Franschhoek	24	59
28/05/04	Kayamandi	85	300
03/06/04	Kayamandi	26	70
14/06/04	Franschhoek	5	22
27/08/04	Franschhoek	5	15
03/10/04	Kayamandi	25	90
16/11/04	Kayamandi	46	200
27/11/04	Kayamandi	35	110
10/12/04	Kayamandi	680	2500
21/12/04	Kayamandi	14	56
24/12/04	Franschhoek	35	101
28/12/04	Kayamandi	6	32
09/01/05	Kayamandi	70	220
20/01/05	Kayamandi	6	35
21/01/05	Kayamandi	241	1000
28/01/05	Franschhoek	7	28
08/05/05	Kayamandi	23	60
15/05/05	Kayamandi	7	20
05/08/05	Kayamandi, Zone F	23	71
03/09/05	Kylemore	1	3
04/09/05	Kayamandi, Zone F	5	14
12/09/05	Cloetesville, 14 Pine Street	1	6
12/09/05	Cloetesville 14 Pine Street	1	6
13/10/05	Kayamandi Zone J	13	45
13/10/05	Cloetesville 35 Eike Street	1	4
18/10/05	Kayamandi Zone J	6	19
23/10/05	Kylemore c/o Hendrickse and Rooi Street	4	13
06/11/05	Kayamandi Zone K	6	18
07/11/05	Kayamandi Zone K	6	18
10/11/05	Kayamandi Zone A	287	636
28/11/05	Kylemore 14 Arum Street	1	2

Date	Area	Number of Shacks	Number of affected persons
29/11/05	Raithby Farm house	1	7
25/12/05	Cloetesville 13 Primrose Str	1	2
13/01/06	Vlottenburg	9	37
06/02/06	Franschhoek Langrug Squatter Camp	3	11
07/02/06	Kayamandi Zone O	250	800
19/02/06	Koelenhof	5	15
19/02/06	Klapmuts	1	5
25/03/06	Franschhoek Langrug Squatter Camp	2	7
26/04/06	Klapmuts La Rochelle	3	9
14/05/06	Jamestown	10	35
27/05/06	Johannesdal, Pniel	3	9
12/08/06	Klapmuts	1	6
24/09/06	Kylemore	3	7
02/10/06	Kayamandi (C147)	1	25
07/10/06	Franschhoek	23	43
14/10/06	Klapmuts	1	3
16/10/06	Franschhoek	4	7
19/11/06	Kayamandi	25	70

Van Wilgen and Scott (2001) found that "the number of days per year when the fire danger index exceeded 50 for 4 days were more frequent during the last decade of the 20^{th} century than during the preceding two and a half decades". Midgley et al (2005) used the United States of America National Fire Danger Rating System (NFDRS) to test whether the frequency of days falling into the different Fire Danger Rating categories will change with climate change. This analysis did not take into account the predicted change in rainfall conditions (a decrease). The results are shown in Table 22.

Table 22 shows that the number of days falling into the high and extreme categories increased. The change was more evident in the Paarl (Cape Winelands) than in George. This indicates more events causing damage to crops and property and resulting in injury and death to livestock and people.

Table 22: A comparison between the number of days in different fire danger rating categories for current climate and for a future climate derived from a climate change prediction. The time periods over which fire danger was calculated were equal for each weather station (3 104 days for Paarl and 3 316 days for George). Taken from Midgley et al 2005.

Weather Station	Fire Danger Rating Category	Burning Index (BI) Thresholds	Reference condition (days exceeding BI threshold)	Climate Change scenario (days exceeding BI threshold)	% Change
Paarl (n = 3104)	Extreme	> 132	6	14	133
	High	123 – 131	7	21	200
	Moderate	95 – 122	38	60	58
	Low	21 – 94	1 728	1 744	1
	Insignificant	0 - 20	1 324	1 244	-0 6
George (n = 3316)	Extreme	> 103	116	153	32
	High	71 – 102	261	359	38
	Moderate	41 – 70	1 323	1 467	11
	Low	19 – 40	1 178	899	-23
	Insignificant	0 - 18	438	404	-8

Disasters such as out-of-control fires raging over extensive areas can give rise to numbers of injured persons far in excess of the coping abilities of the local health services. In fire situations, burn wounds of varying severity and smoke inhalation are the most frequent injury types, with a smaller number of fall-related injuries as persons endangered by the fire try to escape. Fire risks are most severe in extensive informal settlements, when overturned stoves, candles and lamps set the flammable construction materials of the shack-type housing alight. Should the current trend of urbanisation into the study area, specifically of the poor into informal settlements persist, it poses an even greater threat, as informal settlement fires will also remain a factor.

5.2.7 Road Accidents

The National (N1) highway is crosses the District carrying inter-provincial traffic to the Free State, Gauteng and Eastern Cape provinces. It also carries commuter traffic between Paarl and Cape Town, and Paarl and Worcester. The Paarl-Worcester route carried heavily trafficked at an average of 25 600 vehicles per day during a count in 2005 (Cape Winelands District Municipality 2005b). An approximate 19% of vehicles on this route were heavy vehicles, mostly carrying freight (agricultural products, chemicals and perishables). The R44 between the N1 and Paarl is the busiest provincial road in the area with a average daily load of 6 300 vehicles, of which 19% is heavy vehicles. On all roads daily traffic volumes peaks on Fridays and is the lowest on Sundays. Respondents in the Disaster Risk Assessment, which included traffic officers for the area, considered the N1 and R44 both as high risk areas due to the high frequency of use and past incidents. Data to verify this could however not be obtained. The Integrated Transport Plan (Cape Winelands District Municipality 2005b) for the Cape Winelands District Municipality however summarises high-accident zones for the urban roads per municipality.

Table 23: High accident zones (per local municipality) in the Cape Winelands

Municipality	Location of highest accident zones
Stellenbosch	Stellenbosch CBD Helshoogte pass
Witzenberg	Ceres: CBD Tulbagh; CBD
Drakenstein	R44 rural road Paarl; N1/main road junction Paarl CBD
Breede River / Winelands	Ashton: CBD (Main road) Robertson: CBD Montagu: CBD
Breede River Valley	CBD: Intersections with N1 Worcester: CBD

Road and rail accidents will increase with an increase in extreme events linked to climate change. Heavy rains and strong winds will increase the risk on already high risk routes such as the R44 near Paarl, the Du Toits Kloof pass and the N1 and N2 national routes.

5.2.8 Drought

South Africa is a water-scarce country with an economy that relies heavily on the agricultural sector in many areas. In terms of number of people affected, the 2003/2004 drought is listed as the major natural disaster in South Africa. Droughts during 1988, 1986 and 1995 are listed as numbers 2, 3 and 5 respectively on the same list (Sakulski 2007).

The below average and late rain received in the 2003/2004 season resulted in critically low levels of water availability in 8 Provinces. A report on drought stricken areas released in April 2005 by the National Department of Agriculture (NDA) showed that the Cape Winelands was one of the District Municipalities which had been hard hit by drought in the Western Cape (de Lange et al 2005).

In the Cape Winelands District Municipality, areas that were severely affected by drought include those that fall under the Olifants River, the Berg River and Hex River Valley irrigation districts. Witzenberg and Breede Valley Local municipalities were declared disaster areas in 2005 after an extended period of below normal rainfall.

According to NDA estimates, this results in a 4.41% decrease in gross farm income within the deciduous and viticulture industries. Such a decrease represents a 2.94% decrease in the gross regional product (GRP) for the province. Moreover, estimates showed that the wine industry could lose R56.5 million due to the drought. The NDA indicated that approximately 67% of loss in the horticultural sector was experienced by the deciduous fruit industry. The Deciduous Fruit Producers Trust (DFPT) estimated losses in excess of R1 billion. Table grapes producers were said to be among the biggest sufferers as a result of 70% water restrictions in the Olifants River irrigation district. The Berg River area faced 20% water restriction and consequently experienced significant production losses estimated at R1 million. An estimated R1.4 million in losses on export cartons of table grapes were reported in the Hex River valley. The livestock and wheat industries were also severely affected by the drought.

The Western Cape received R15. 85 million for drought relief for the 2003/2004 production season, from which 9.2% was paid to approved farms. R6 27 803, 14 was available for drought relief in the 2004/2005 production season. R8.0 million was made available from government as drought relief bringing the total to R8.6 million available.

Persistent drought conditions normally lead to a focussed attention on food security, specifically in developing countries and in agricultural driven economies such as the Cape Winelands. Not only does the reduction in the production of food to feed the community, including their work forces and their immediate dependants (those farming commercially and people living off the land) but also to the markets they provide for. Production of fruit for own consumption or export may drop dramatically, and will pose a threat to the livelihoods of farm workers and farmers. Lack of nutrients and regular fresh food specifically impacts on those already poor and immune compromised. Subsistence farming is however not a big part of the Western Cape economy, so the direct impacts of malnutrition should not pose a huge risk.

This last major drought only illustrates the magnitude of impacts on the region. Based on the fact that 38% of the Cape Winelands population is currently directly employed in the agricultural sector, drought is considered as a major risk in the area and will also be under a future climate (refer to Chapter 2). The impacts on agriculture and the resulting impact on diseases associated with poverty will be discussed in a following section.

5.2.9 Earthquake risk

Earthquakes (seismic activity) emerged as a major threat during the risk assessment. Although earthquakes are not directly related to climate change, it may aggravate, or cascade, disasters caused by climate change and are therefore discussed.

The information below is quoted from a specialist report (Hartnady 2005) on seismic risk requested as part of the risk assessment process.

"The Western Cape was already identified as a zone of seismic hazard on a mid-nineteenth century global earthquake map. In spite of this, the earthquake history of the Western Cape, identified as a zone of seismic hazard on a mid-19th century global earthquake map, remains incomplete, vague, and often erroneous in the public memory. Although detailed scientific opinion may vary, there is little doubt that the Western Cape is at risk from significant earthquake events. The Tulbagh-Ceres earthquake, which occurred in the now Cape Winelands District Municipality area in September 1969 is probably the best-known historical seismic event in the Western Cape, but there are geological indications of previous far stronger earthquakes in this region. In the area around the Toorwater hot spring between De Rust and Uniondale/Willowmore, a ~100 km-long, youthful fault-scarp with ~4 m surface displacement, bears testimony to a prehistoric Southern Cape earthquake of possible magnitude ~7.5."

"Current probabilistic seismic hazard assessment predicts that, for any 50-year time interval within a wide zone between Ceres and Cape Town, there is a 10% probability that peak ground acceleration (PGA) will exceed 0.16g-0.20g, corresponding to shaking with intensity close to 8 (VIII) on the Modified Mercalli (MM) scale. However, seismic hazard in the Western Cape area is probably underestimated. Future large earthquakes of low annual probability (1:1 000 or greater, associated with at least ~0.3g acceleration, equivalent to shaking of MM intensity ~9 (IX)) are a significant hazard, particularly for "lifeline" infrastructure (dams, pipelines, railways, major trunk roads and bridges). Although a "maximum earthquake magnitude" around M 6.6 is implied by a calculated upper bounding PGA limit of 0.6g (or MM intensity 10 (X)), a revised method that incorporates the GPS-measured rates of displacement across the seismic belts is necessary in case this parameter has been underestimated."

The extreme severity of the hazard, coupled with very little manageability and large vulnerabilities, escalated this hazard to one of the major risks in the area. A study to investigate the full impact and suggest possible risk reduction measures was strongly recommended and should commence shortly as the necessary funding becomes available.

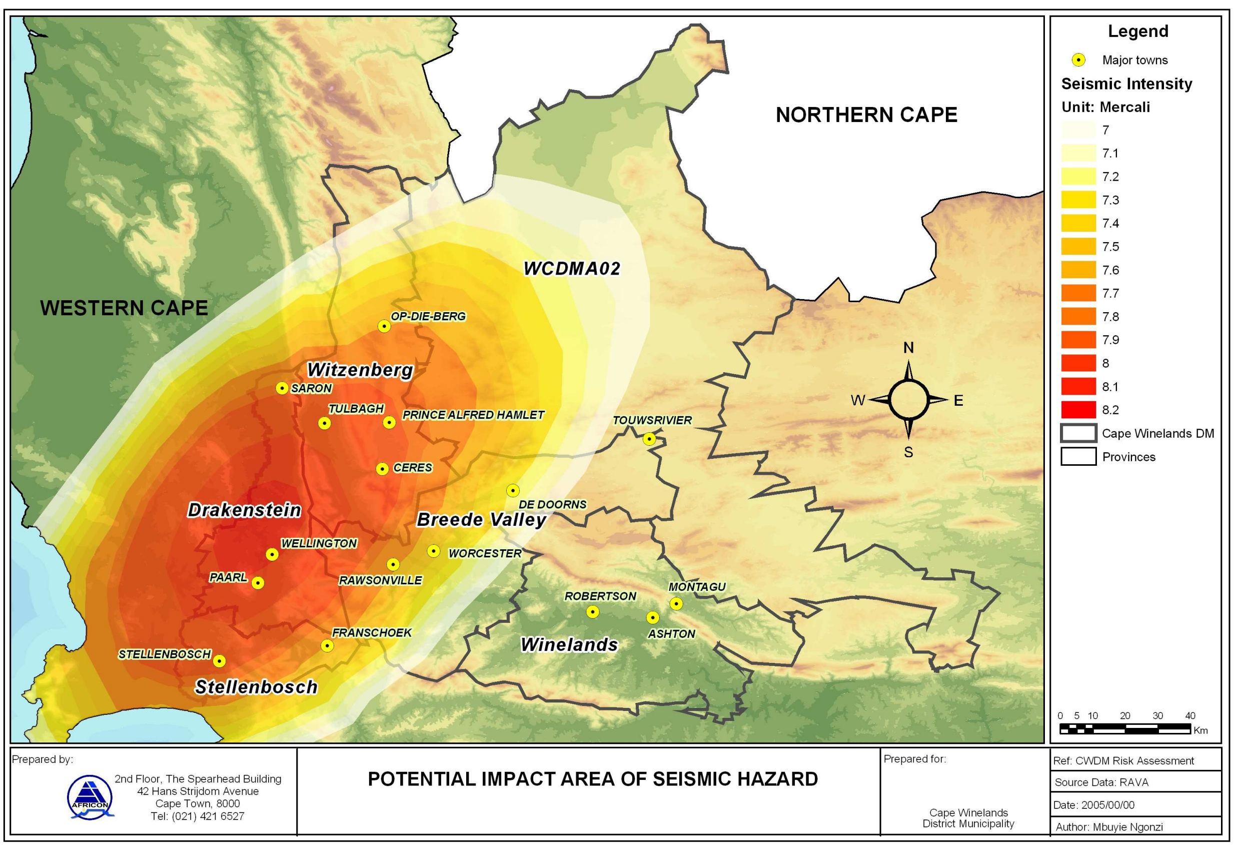

Figure 18: Seismic intensity levels

5.2.10 Biological hazard

Biological hazards are processes of organic origin or those conveyed by biological vectors, including exposure to pathogenic micro-organisms, toxins and bioactive substances, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Examples of biological hazards are outbreaks of epidemic disease, plant or animal contagion, insect plagues and extreme infestations. Unlike hazards such as geological hazards where the existing geological formations provide scientific clues to possible risks, biological hazards need not be habitually present in an area to give rise to an unexpected disaster. In the sphere of biological agents of risk, a survey of diseases that are habitually or usually present in a region does not adequately cover the possible risks posed by human and animal diseases. Disease-causing pathogens do not respect borders and can invade a region in so many ways that only a general overview of the pathways of disease transmission and examples of the pathogens involved are normally given when assessing risk.

The categories of biological health hazards do however include much more than just the microbiological organisms causing human disease. It also includes, amongst others, animal diseases with an impact on human health or economic well-being, proliferation of pest plants or plant diseases causing crop failure, upsurge in the numbers of problem animals, etc. A change in health status is also often a secondary impact of another incident, such as cholera following a flood event, outbreaks of measles in a refugee camp, or environmental degradation and should not be regarded as of secondary importance.

The respondents in the risk assessment listed polio, measles, malaria and meningococcal meningitis as having occurred in the past in the area and was therefore assessed and included in the discussion. Specific incidences were however not listed. The area is not an endemic malaria area, and is unlikely to become that, as malaria is more prevalent in subtropical climates and summer rainfall conditions. It poses a major risk in others parts of the country (endemic areas in Mpumalanga, Limpopo and KwaZulu-Natal) and is regarded as one of the world's most serious and complex health problems (Turpie et al 2002, WHO 2005). It is often mentioned as one of the concerns when discussing climate-related health threats. Of all the factors that govern that risk of malaria, climate is considered the most important (Craig and Sharp 2000, Craig et al 1999, http://www.health24.com/news/enviro_health, Morse 1996). Turpie et al (2002) further states that malaria incidence and prevalence have increased since the 1970's in South Africa. The increase is not only due to climatic factors (warm and wet years) but to a steady migration (mainly from Mozambique), drug resistance and reduced DDT spraying of housing (Gubler 1998). The economic cost of increased malaria risk due to climate change is estimated to be R1mil in 2010, as well as additional 2100 deaths annually. Spalding-Fletcher (2005) predicted that the population at risk will quadruple by 2020 to 36 million. Midgley et al (2005) predicts that malaria is not a likely threat to the Western Cape, but that the endemic risk zone in the east of the country will geographically increase slightly and expand south and west due to incidence at higher latitudes (Epstein 1997).

South Africa was declared polio-free in 2006 based on the last recorded outbreaks in 1989. This does not however imply that the country is risk-free. The outbreak of the virus in Namibia in 2006 has prompted an emergency polio immunisation campaign in four districts (Namakwa, Siyanda, Metswedeng, Amatole) based on their high risk. The Western Cape currently has the highest rate of childhood immunisation for this virus in the country (Department of Health 2007).

Similar to polio, measles is a highly-contagious vaccine-preventable disease caused by a virus. There exists a vaccine administered during childhood that can prevent the transmission of measles. It is one of the most readily transmitted childhood diseases of which more than 50% of the deaths occur in Africa. The majority of measles deaths occur in countries with a GDP of less than $1 000 (Department of Health 2007). No cases of measles were reported in the Cape Winelands between 2002 and 2005 (Groenewald 2006). There is an ongoing initiative in South Africa to eradicate measles by immunisation campaigns. In the Western Cape the 1st dose coverage has increased from 71% in 2002 to 89% in 2005. High immunisation coverage will contribute significantly to achievement of the Millennium Development Goals of reducing mortality rate among children by two thirds by 2015.

Meningococcal infections are highly infectious and are associated with crowding, specifically during winter months. Of the reported 57 cases in the eastern Cape Winelands between 2000 and 2005, 6 deaths occurred (Groenewald 2006). More recently, a Stellenbosch University student died within 2 days of being diagnosed with meningitis in May 2007.

A characteristic of the outbreak of plant and animal disease is that they often transcend boundaries. Outbreaks are considered possible disasters due to their impact on the economy and food security.

Examples include anthrax, foot-and-mouth disease, rinderpest, African swine fever, virulent avian influenza and locust swarms. Some animal diseases can cause illness in humans as well. Rabies, for example, is primarily a disease of animals, but the rabies virus can be transmitted to humans, commonly through the bite of an infected carnivore. Animals can either be the mode of transmission (the vector) or a source (reservoir) of disease. Recent outbreaks of animal disease in the study area include:

- Porcine Reproductive and Respiratory syndrome (Blue Ear Disease): The recent outbreak in April 2005 resulted in the culling of 8 000 pigs. It caused massive losses in production.
- African Horse sickness. The disease is endemic to the African continent and is characterised by respiratory and circulatory damage that is accompanied by fever and loss of appetite. It is transmitted by midges, which need an infected horse as a source of virus for spread of the disease. It has the potential to spread very rapidly to other horses, irrespective of farm boundaries. It occurs mostly in the warm, rainy season when midges are plentiful and disappears once the cold weather sets in. An outbreak occurred in the Western Cape region in late January 2004. Since the beginning of the outbreak a total of 16 horses were confirmed dead and approximately 20 confirmed clinical cases as a result of Horse Sickness. All cases were shown to be of the Serotype 1, which is suspected to have been introduced from outside the control area, possibly by an illegal movement of a sick horse or a horse incubating the disease. (Louw EJM 2005)

5.2.11 Environmental degradation

5.2.11.1 Air pollution

Details of existing levels or air pollution could not be obtained. It is in general prevalent in the industrial areas and during inversion conditions. Conditions conducive to the formation of inversion layers (discussed in chapter 2) is said to increase pollutants leading to an increase in air pollution levels and resulting in an increase the incidence of conditions such as hay fever, sinusitis and asthma. This will be aggravated by a higher incidence of fire and strong winds in the Cape Winelands.

5.2.11.2 Water pollution

Although water pollution was identified by a limited number of respondents in the Disaster Risk Assessment, expert analysis (Barnes 2003) and recent media coverage indicated a much bigger risk than that of the obvious environmental consequences, and is therefore discussed in detail here. Water quality in the Cape Winelands has become a major issue in the agricultural, health and resource protection fields. Debates between the Department of Water Affairs and Forestry, the municipalities, researchers and farmers and finger-pointing are the norm in the area, and the solutions seem not to be forthcoming. Barnes (2003) lists water pollution (poor water quality) as having the following consequences:

- Health consequences
- Environmental consequences
- Consequences for tourism
- Agricultural impacts

Water has a unique double role in health and disease. It is essential for hygiene and cleansing, but polluted water is also a very efficient carrier of many diseases. Water-related diseases are categorised (by Feachem 1975) as:

- Faecal-oral (water-borne or water-washed), for example diarrhoeal diseases, infectious hepatitis
- Water-washed only, for example scabies, conjunctivitis
- Water-based, for example trachoma, dracunculiasis
- Water-related insect-vector transmitted, for example malaria

A list of orally transmitted waterborne pathogens and their significance in water supplies are given in Table 24. Water-borne or water-washed diseases are mostly associated with high faecal contamination and are transmitted through the faecal-oral route. This mostly results in diarrhoeal diseases, especially in children. The health of children is therefore often taken as an indicator of the general health status in an area (refer to 5.1.4). The Cape Winelands is heavily burdened by diarrhoeal disease indicating poverty prevalence and inadequate sanitation and water supply. *Escherichia coli* is commonly used as indicator organism as warning of faecal pollution in water (Barnes 2003). *E. coli* was chosen as biological indicator of water treatment safety during the

1980's. It is a member of the family Enterobacteriaceae that grows at 44 to 45 degrees Celsius on complex media. Some strains grow at 37˚C. Drinking water should contain no *E. coli* organisms. (WHO 1997).

Table 24: Orally transmitted waterborne pathogens and their significance in water supplies (WHO 1993)

Pathogen	**Health significance**	**Persistence in water supplies**[a]	**Resistance to chlorine**[b]	**Relative infective dose**[c]
Bacteria:				
Campylobacter jejuni *C. coli*	High	Moderate	Low	Moderate
Pathogenic *Escherichia coli*	High	Moderate	Low	High
Salmonella typhi	High	Moderate	Low	High
Other *Salmonellae*	High	Long	Low	High
Shigella spp.	High	Short	Low	Moderate
Vibrio cholerae	High	Short	Low	High
Yersinia enterocolitica	High	Long	Low	High
Pseudomonas aeruginosa	Moderate	May multiply	Moderate	High (?)
Aeromonas spp.	Moderate	May multiply	Low	High (?)
Viruses				
Adenoviruses	High	?	Moderate	Low
Enteroviruses	High	Long	Moderate	Low
Hepatitis A	High	?	Moderate	Low
Enterically transmitted non-A and non-B hepatitis viruses, hepatitis E	High	?	?	Low
Norwalk virus	High	?	?	Low
Rotavirus	High	?	?	Moderate
Small round viruses	Moderate	?	?	Low (?)
Protozoa				
Entamoeba histolytica	High	Moderate	High	Low
Giardia intestinalis	High	Moderate	High	Low
Cryptosporidium parvum	High	Long	High	Low

[a]Definition of period detected in water at 20ºC:- *Short*: up to 7 days, *Moderate*: 7-30 days, *Long*: >30 days

[b]Water treated at conventional doses and contact times - Moderate resistance: organisms not completely destroyed

[c]Dose required to cause infection in 50% of healthy adult volunteers. It may be as little as one infective unit for some viruses.

The presence of *E. coli* indicates either that water has been faecally contaminated and/or that water treatment has been ineffective. For irrigation purposes the international requirement is that the level should not rise above 2 000 organisms per 100 ml water. Above that level, the hazards increase with increased organism count and no direct contact with humans, animals or crops should occur. Such water can be dangerous to health as high levels of *E. coli* also indicate that there is an increased likelihood of other pathogenic organisms being present (Louisiana State University 1999). Data from the National Microbiological Monitoring programme for the Berg River are summarised in Table 25. It shows an alarmingly high frequency of measurements where the water is not suitable for drinking without treatment. The frequency decreased somewhat with limited treatment of the drinking water. In terms of health, the concern however is the high risk being posed by coming into contact with untreated water, specifically for those living in informal settlements and rural areas where the river is the only available water source. With the exception of January, the figures for all months show that at more than 50% of the sampling points, contact should be avoided with untreated water.

Table 25: Percentage of sampling points in the Berg River WMA per month in 2006 posing a 'high'* risk for use (data obtained from National Microbial Monitoring programme, DWAF)

Water Use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Drinking	95	94	95	100	100	100	100	100	100	100	100	100
Drinking: limited treatment	43	59	55	66	23	18	25	8	13	25	36	25
Contact	43	53	50	59	57	57	63	58	69	50	55	69
Irrigation	29	53	23	27	53	46	50	46	56	44	48	63

*Risk based on *E. coli* levels per 100 ml water:

> 10 : high risk when drinking water

> 2 000 : High risk from full or partial contact

> 4 000 : High risk for eating crops that are eaten raw

> 20 000 : High risk when drinking after only limited treatment

In terms of agriculture, the threshold value of 4 000 *E. coli* per 100 ml water is considered to be of "high" risk. This value was recently increased for 2 000 *E. coli* per 100 ml water by the Department of Water Affairs and Forestry. Although unpublished, the generally internationally accepted threshold value for irrigation water used on export fruits to the European Union is 1 000 *E. coli* per 100 ml water.

The existing capacity problems of the sanitation works is exacerbated by the influx (migration) into the region. The possible economic impacts of pollution on the Cape Winelands rivers should not be underestimated. Overseas consumers are increasingly unwilling to pay high prices for produce from developing countries where the production methods either carry health risks or are associated with unsound ecological practices. The export markets are crucial to the economic survival of the agriculture industry in the Western Cape. The situation is closely monitored in South Africa and a first warning has already been issued (pers comm. Louw 2006) to address the problems surrounding the quality of irrigation water to avoid European rejection of the exports.

Apart from agricultural activities, there are extensive tourist developments in the Cape Winelands especially along the Eerste River. The visitors to these facilities should be prevented from contact with the river water to avoid illness.

The poor water quality is regarded as a serious form of environmental degradation, technically a hazard in itself, but the secondary impacts are those of most concern to the candidate. Not only is agriculture affected by the environmental degradation, which is directly affected by climate change, but climate change will also impact upon agricultural production. Agriculture provides an income to 38% of the population as discussed earlier in this chapter. The health of the population is also shown to be affected by their socio-economic status. The health of the population is therefore indirectly dependant on the impacts of climate change on the agricultural sector in the study area and is discussed in the following section.

5.3 The vulnerability of the agricultural sector and its relationship with health

When assessing disaster risk, one tends to focus on direct impacts and hazards. In the case of the Cape Winelands, the economy is however extremely vulnerable with 38% of the population being directly supported by the agricultural industry. **Risk** is a function of **hazard, vulnerability** and the **capacity to cope** (or manageability) with a hazard. When an external factor, such as climate, changes it is crucial to assess the impact of this factor on the each of the parameters, i.e. the hazard, the vulnerability of the community and its coping mechanisms. This viewpoint is strongly confirmed by Hales (2001).

Plant growth and therefore food production is determined by temperature, moisture, soil conditions and solar radiation. Any change in these conditions will therefore have implications for agriculture (Cartwright 2002).

5.3.1 The fruit industry case study

Cartwright (2002) analysed the impact of climate change on the production of Braeburn apples in the Western Cape. A climate envelope capable of describing the temperature requirements as constructed by analysing Braeburn physiology and taking into consideration chill units, heat units, diurnal range and sunburn index that need to be satisfied during the different phonological stages, were developed. Mean 1820 to 2000 temperature parameters at 27 stations were tested for compliance with these envelope conditions. The GCM-related perturbations of these mean temperatures were tested for compliance for Braeburn production by 2020 and 2050. Compelling evidence was produced that the ability to produce for international markets will become restricted to high-lying areas of the Koue Bokkeveld, Ceres, Grabouw and Villiersdorp (all in the Cape Winelands District) within the next twenty years and limited to certain areas within the Koue Bokkeveld by 2050. This can be ascribed to the need of apple trees for satisfying the chilling requirements for economically viable production. The findings are illustrated in Figure 19.

Although Cartwright's study only assessed the impact of climate change on Braeburn apples, similar trends can be expected for other varieties. In general, the fruit industry is expected to be impacted upon more by extreme events (predicted to increase with climate change) than by changes in averages (pers. comm Wand 2006). Heat waves normally contributes to 10% of all losses during an average year, but is said to rise to 50% should temperatures of higher than 35˚ Celsius occur during summer. Winters are already becoming too warm, and apple farming activities would have to move to higher latitudes. Due to it's location on the southernmost tip of Africa, this is not an option for the Western Cape fruit industry. Water quality and quantity is also of importance to ensure quality fruit (pers comm. Wand 2006). Fruit trees are sensitive to waterlogging, especially in spring and early summer. Should soil be saturated, extreme rainfall and flooding can have a major impact. The buffer capacity for withstanding drier conditions is said to be two to three years. According to Wand (pers comm. 2006) fruit farmers are already starting to substitute orchards (some very old) with vineyards. Farmers in geographical (in terms of suitable climate conditions) marginal areas, such a Grabouw, and specifically those with substandard farming practices is expected to be affected most by an increase in temperature and changes in rainfall. The economic impacts of climate change on the industry are discussed in the following section.

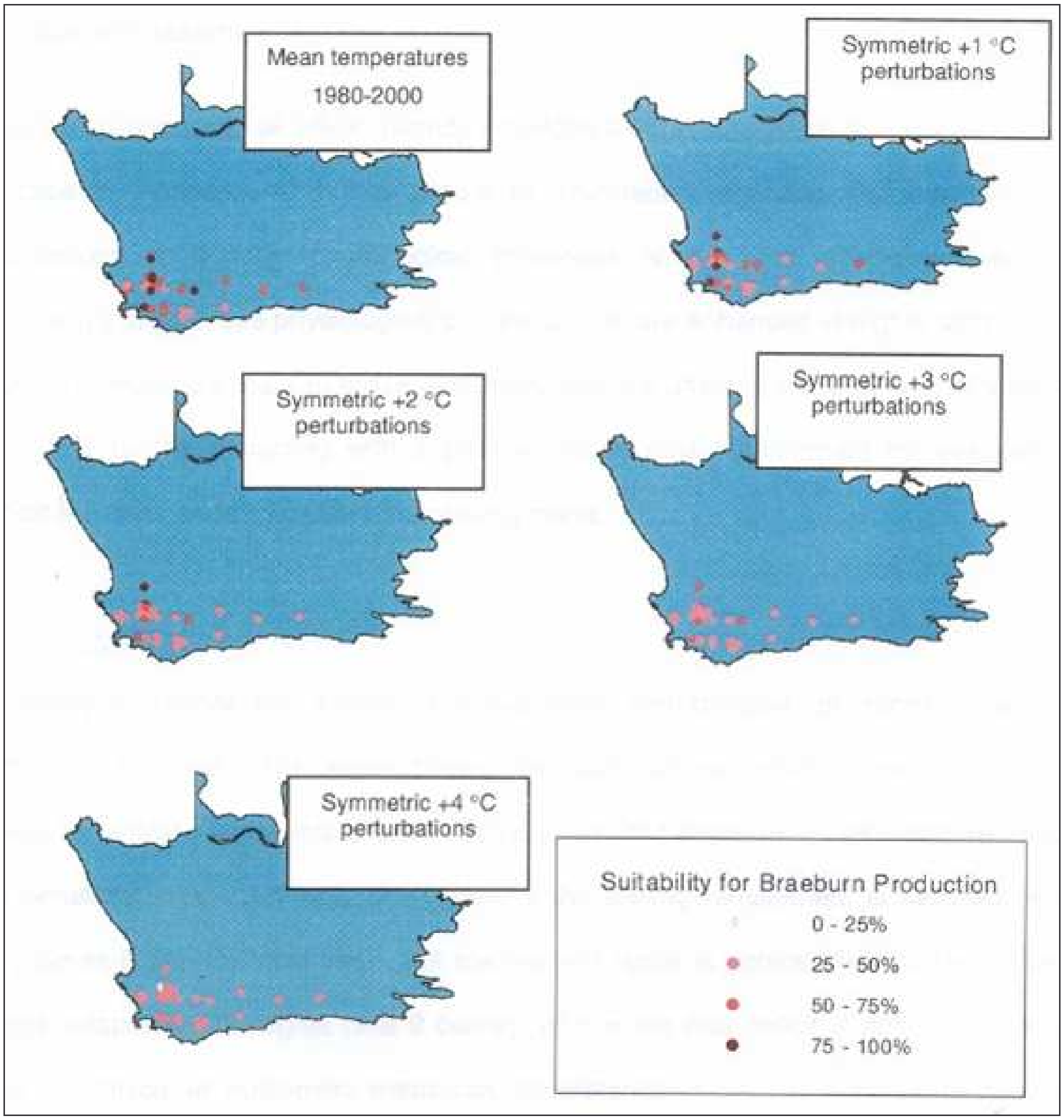

Figure 19: Illustration of the suitability of 27 stations within the winter rainfall region of South Africa to satisfy the climate envelope for Braeburn apple production under different warming perturbations. The general trend towards lighter shades of red indicates reduced suitability at higher temperature perturbations. The patchiness in the distribution is indicative of the diverse micro-climates and topography within the winter rainfall region. (Figure and caption taken directly from Cartwright 2002)

5.3.2 Climate change in the Berg River Basin

Unless stated otherwise, all information discussed in this section was obtained from Louw (pers comm. Louw 2006, Louw et al 2001). The study focuses on the Berg River Basin, the upper Berg being located in the Cape Winelands District (Figure 20).

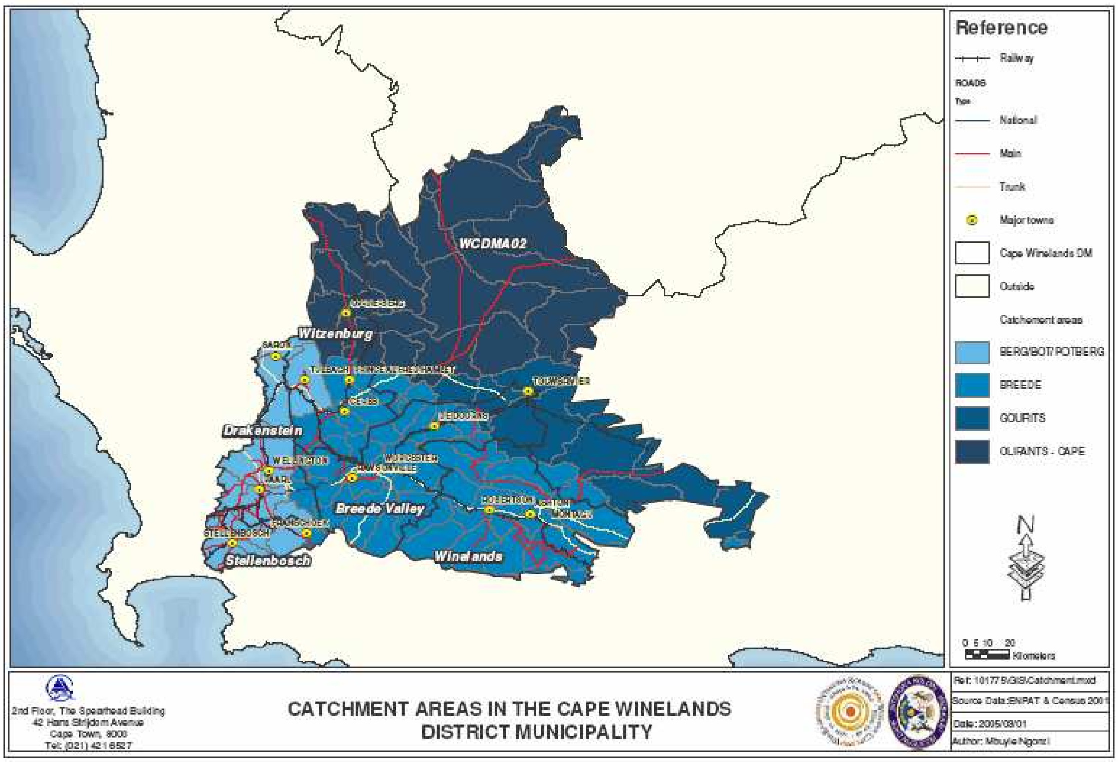

Figure 20: Catchment areas in the Cape Winelands District Municipality

5.3.2.1 Background

The Berg River and its tributaries are the major source of urban water supply for the Cape Town metropole and the agricultural sector. It provides irrigation water for around 15 000 hectares of mostly export crops. The rapid growth rate of the metropolitan area, mainly due to migration of the poor and economic development of the area, led to a three-fold increase in urban water demand between 2002 and 2005. It has resulted in an increased competition for water between urban and agricultural use, exacerbated by a high inter-annual variability of rainfall. Alternative water sources and water demand measures are constantly being assessed, and have, amongst others, led to the building of the Berg River Dam (previously known as the Skuifraam Dam). None of these water planning scenarios, however, consider the impacts of climate change on the water resources.

5.3.2.2 The Berg River Dynamic Spatial Equilibrium Model (BRDSEM)

Louw (Louw DB 2005) and his colleagues firstly estimated the potential impacts of climate change scenarios on water supply in the Berg River Basin considering changes in runoff, evapo-transpiration and surface evaporation. These physical impacts were then translated into monetary terms (losses or gains) for different water users, both urban and agricultural. The project team developed the Berg River Dynamic Spatial Equilibrium Model (BRDSEM), a dynamic, multi-regional, non-linear programming model to achieve these objectives.The BRDSEM model is illustrated in Figure 21 and shows the core of the model and the three sources of external information, namely climate, hydrology and inputs from policies, plans and technologies.

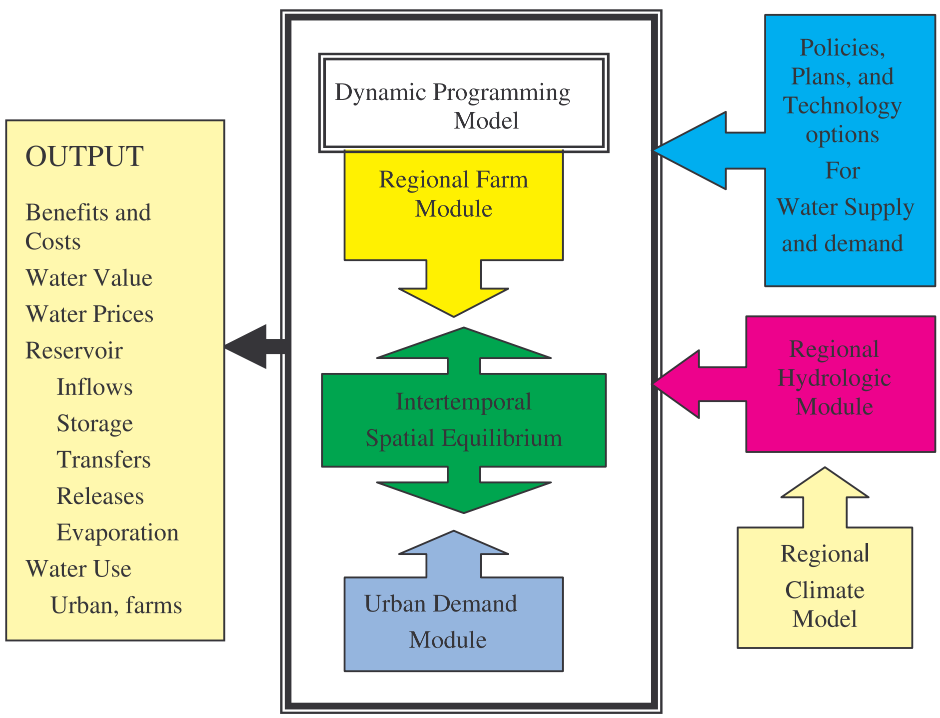

Figure 21: The BRDSEM schematic diagram (from Louw DB 2005)

The BRDSEM was developed as a water planning and evaluation tool rather than predictive one. It compares the benefits and costs and economic impacts of alternatives for coping with long-term water shortages due to climate change. The economic value of the net returns to water for 3 climate change scenarios, 2 scenarios for urban water demand, 4 policy regimes for water allocations and with/without the additional storage of the Berg River Dam were estimated. The benefits and costs associated with adapting to climate change were also considered for two of these options under all three climate change scenarios.

5.3.2.3 Main conclusions

The model produced many results, such as benefit-cost perspective of construction of the Berg River Dam, the implementation of efficient water markets, agricultural and urban water consumption, et cetera, that will not be described here. The relative and absolute damages attributable to climate change were much greater under the current water allocation regime than under the efficient water market regime. Under the low urban water demand scenario, damages ranged from R3 billion to R6 billion, depending on the climate scenario used. Under a high urban water demand scenario, damages increased to between R13 billion and R27 billion. For the efficient water market scenarios, the figures remained the same for low urban water demand but were reduced to R7 billion to R13 billion for the high demand scenario. In summary it can be said that climate change will have a severe impact on agriculture in the Berg River system (pers comm. Louw 2006). Not only will the demand for water from both urban and agricultural sectors create immense competition in the water market, but the multiplier effect of agricultural losses poses a big threat to the local economy. This will be discussed in the following section.

5.3.3 The multiplied cost of climate change

Eckert et al (1997) used a social accounting matrix to determine the fixed price multipliers of the Western Cape agricultural sector. These are shown per sector in Table 26. This table illustrates the multiplier effect of demand for agricultural products. For example, R1.00 of additional demand for the horticultural sectors output increases the value added (provincial) by R1.40 requires R0.20 of imports and contributes R0.24 to revenue. The most important aspect in terms of this study is however the additional 92.8 number of person-years employment for the extra R1.0 million final demand.

Table 26: Fixed price multipliers for commodity and sector groupings (Louw et al 2001)

	Employment[a]	Value added[b]	Imports[b]	Gov revenue[b]
All agriculture	82.8	1.29	0.21	0.26
Cereal	26.1	1.02	0.27	0.27
Other crops	70.8	1.36	0.19	025
Horticulture	92.8	1.40	0.20	0.24
Livestock	88.4	1.25	0.20	0.27
Agri-business	39.7	1.02	0.26	0.2
Non-agriculture	29.4	1.1	0.25	0.22

a Number of person-years employment created per R1 million rand final demand

b Rand value per additional R1 million final demand

The opposite is also true. Should the demand for a product decrease, or the industry is impacted upon by climate change, similar losses would be suffered. The salaries paid to the farm workers and those in the related industries are spent in the local towns, supporting many small businesses in the province. The threat of climate change to agriculture therefore also poses a huge risk not only to the related industries, but also those indirectly being supported by earnings in the sector. Eckert et al (1997) quoted in Louw and van Schalkwyk (2001) calculated that a 10 percent water restriction (read: 10% less water available) translates to a R100 to R200 million less expenditure in the rural areas – just in the Upper Berg River. It will certainly spill over in the rest of the economy.

5.3.4 The export industry

The threat of climate change on the Western Cape agricultural industry is immense. Not only is the industry providing employment for 38% of the population in the Cape Winelands, but is also indirectly contributes millions of Rands to the local economies of the area.

Another threat to the agricultural industry is the water quality used for irrigation of export crops. The European Union imports South African fruit from, amongst others, the Cape Winelands, and has recently (2005) issued a warning that the quality of the irrigation water is substandard (pers comm. Louw 2006) and that all fruit exports may be terminated. The water quality (or lack thereof) is mainly a result of the informal settlements along the major rivers, as well as the failure of sewage works of the area as discussed in earlier chapters, and is of a magnitude to pose a serious threat to the export industry. This factor only contributes to an industry already under threat to a hanging climate. As discussed earlier, the concentrations of *E. Coli* is predicted to increase under higher temperatures.

5.3.5 Agriculture and health

The above discussions on climate and agriculture may raise questions on the applicability to this research. The economic vulnerability to climate change is however a major threat to health in the area, based on the existing conditions, and is likely to increase. As mentioned in previous chapters, agriculture provides a livelihood to 38% of the population in the area. Any threat to this, threatens the socio-economic well-being of the society. Socio-economic well-being is directly related to the health profile of a society. It is a well-known fact (see pervious chapter) that the rich and the poor are threatened by a different disease hazard. Although the incidence and prevalence are increasing amongst the poor, the rich are more prone to the so-called life-style diseases such as heart disease, strokes, certain cancers and obesity (Steyn 2006). Diseases linked to poverty include malnutrition, diarrhoea associated with poor sanitation, high childhood mortality rates, tuberculosis and a larger susceptibility to infectious disease due to lower immunity levels. This is exacerbated by a relatively higher birth rate, a feature of developing nations. In South Africa, it is further linked to a higher HIV/AIDS prevalence amongst the previously disadvantaged groups (Bradshaw and Steyn 2001).

5.4 Methodological limitations

The probable health risks discussed in the previous sections were based on an assessment of the existing health profile, the existing disaster risks and likely future disaster risk. The following limitations in this methodology should however be kept in mind:

- The use of questionnaires was not an optimal method to gather the information needed and the results must be interpreted with caution. The questionnaires were generically designed for use in South Africa and included, for example, malaria, which is not endemic to the study area. This resulted in the identification of hazards that had to be assessed based only on its inclusion in the hazard identification stage which was not applicable to the study area.
- The respondents from the various local authorities did not always represent the optimal choice of staff members to provide the necessary information. Many of them had a background in mostly traffic or fire services, and they were not suitably qualified to complete an assessment of

this nature. Although each district was requested to workshop the completion of the questionnaires amongst themselves in an inter-sectoral forum, this did not occur, except for the Breede Valley local municipality.

- The quantification of existing disaster risk was base on a very simple mathematical model. Although currently seen as international best practice, the method remains of unproven practical application, mainly due to the complex relationships between the variables. The aspect of vulnerability, specifically, is still largely regarded as unquantifiable due to the many parameters that may contribute to this complex state. These parameters and their inter-relationships still remain to be determined.
- The quantification of risk is further severely limited by the lack of reliable data at a district level, such as records of fires and traffic accidents, disease prevalence and incidence and immunisation rates.

5.5 Implications for the Cape Winelands District Municipality

The risk assessment identified immense societal and economical vulnerabilities, which, if not addressed will contribute to increased future health risk profiles under a changed climate. It is the opinion of the candidate that the biggest future threat to health in the area are water-related biological hazards and poverty related diseases, a secondary impact of climate change on agriculture. Both are inter-dependent, with an extensive socio-economic component. These results were unexpected and illustrate the importance of analysing secondary impacts and vulnerabilities when conducting a risk analysis. The results of the risk assessment illustrate an area already under sizeable threat from existing hazards. This resulted in high risk scores due to a lack of coping capacity or general lack of awareness of the officials and the public. An external trigger, such as climate change, will result in a fully fledged disaster within municipalities that are largely unprepared for it. Chapter 6 suggests broad risk reduction strategies to address these threats and in Chapter 7 specific recommendations for action is made to address the risk per sector.

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CHAPTER 6

Risk Reduction : strategies towards mitigation

6.1 Introduction

The inhabitants of the earth depends on its ecosystems and the services they provide, such as food, safe water, disease management, climate regulation, spiritual fulfilment and aesthetic enjoyment. Humans have changed these ecosystems rapidly over the past 50 years – more rapidly and extensively than is any other time in history, largely to meet the demand for food, fresh water, timber, fibre and fuel. The full costs of these changes are only now becoming apparent (Sarukhan & Whyte 2005).

Climate change is internationally and locally considered a major threat by various researchers - in areas such as water, housing, biodiversity, agriculture, health and therefore, by implication, disaster management. Article 35 of the World Summit on Sustainable Development, held in 2002 in Johannesburg, focussing on climate change, states that " …an integrated, multi-hazard, inclusive approach to address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, is an essential element of a safer world in the twenty-first century" (Schulze 2003).

When attempting to assess the impacts of climate change on health, the approach should be inter-sectoral and holistic. Many studies (Patz et al 1998, Craig et al 1999, Cross and Hyams 1996, Epstein 1997, Curriero et al 2001, Rose et al 2001, Fleury et al 2006) have attempted to quantify the empirical relationships between climate variables and incidence of a certain disease. These have succeeded to a certain extent, and have done tremendously valuable work in exploring hazards, but have not taken vulnerabilities and coping mechanisms into consideration. As illustrated in this research, the impact of climate on health cannot be assessed in a closed system of cause (weather parameters) and effect (disease incidence). Research in monitoring the health impacts of climate change should therefore be directed towards the following five aims:

- Early detection of the impacts,
- Improved quantitative research on health/climate links,

- Improved analysis of the vulnerabilities,
- Prediction and validation of future impacts and
- Assessment of the effectiveness of risk reduction and adaptation (Campbell-Lendrum et al 2002).

Vogel and Reid (2005) reiterated this by stating that impacts that result from climate change are usually aggregated or reduced by many mechanisms, such as policy, but is known to operate at different scales.

The previous chapters described a study area facing several hazards, some directly impacted upon by climate change. It also illustrated the complex inter-dependencies of the impact of climate change on health. The use of the risk assessment methodology enforced a necessary focus on the vulnerabilities of the community, an aspect often ignored in medical geography. The vulnerabilities of specifically some of the communities in the study area increased the health risk under a changed future climate. Many of these vulnerabilities can be mitigated by focussing on increasing general resilience, as well as strengthening the capacity to cope through improved health care. Strong local and national commitment is required to reduce risk. Risk reduction must be part of municipal, provincial and national decision making and planning. This necessitates an approach that is inter-sectoral and inter-departmental. Spatial and economic planning and the recognition that each of these should take place on a scale larger than the municipal borders are of utmost importance. The Disaster Management Act, Act 57 of 2002, (South Africa 2003) aptly instructs that disaster management must become 'everybody's businesses', which is certainly true in the case of human health in the Cape Winelands.

6.2 The role of government in risk reduction

Internationally governments around the world have committed to take action to reduce disaster risk, and have adopted a guideline to reduce vulnerabilities to natural hazards, called the Hyogo Framework for Action (UNISDR 2004). The first priority for action is to make disaster risk reduction a priority with a strong institutional basis for implementation. Risk reduction efforts in South Africa are currently neglected and one-dimensional, and although better than nothing, it is not ideal. It is the responsibility of the Disaster Management Centre (National, Provincial and Municipal) to research possible threats, and to coordinate the efforts to reduce risk. The recognition of the inter-dependability of these risks and the associated multi-sectoral cooperation to reduce them, are not common. Public sector thinking on all levels, unfortunately, generally exists in departmental silos, and is often associated with thoughts such ‘this is not in my job description’ and ‘is not my problem’. Once again, the challenge is for the Disaster Management Centre to consistently educate, create awareness and coordinate. Local politicians must accept responsibility for the quality of people's lives and the risks they face. They can only do so from an informed perspective, and hopefully then adapt the adage that ‘prevention is better than cure.

6.3 Risk reduction measures

Theoretically, the measures that can be considered to reducing the risk for a community or an area are five-fold and are taken from Botha and Louw (2004) with additions by the candidate. They are categorised as:

- Physical planning measures
- Engineering construction measures
- Economic measures
- Management and institutional measures
- Societal measures.

6.3.1 Physical planning measures

Physical planning measures include the location of public sector facilities that can reduce the vulnerability of the area. It involves schools, hospitals and major infrastructural elements like waste water treatment works, power transformers and telephone exchanges. In terms of flood reduction, for example, the building of dams, flood control reservoirs and dikes can be considered (Kabat et al 2003). Of importance is however the consideration of disaster risks in spatial planning. The development of residential areas and the supporting infrastructure should always be done is such a way to reduce risk, rather than increase it.

6.3.2 Engineering construction measures

Two types of engineering construction measures are possible. The first option results in stronger individual structures more resistant to hazards, such as earthquake resistant buildings, and secondly those that create structures to protect and alleviate against hazards such a as dykes, levees and dams. Structural aspects of building construction used in an earth tremor prone area for example are one of the important risk indicators of injury in case of a major earthquake. If floors of multi-storey buildings fail in a V-shape, then pockets of free space are more likely (and thus more survivors) than when the floors collapsed in a pancake fashion. In damaged buildings with pan caked floors, much higher fatality rates and rates of serious injury are observed. Brick buildings withstand smaller tremors better than more traditional mud-and-stick constructions, but in severe quakes the fatality and injury rates are much higher due to severe structural damage. Information should be used to assess the buildings of existing hospitals and other medical facilities for earthquake damage risk, so that they can be made safer in order to preserve as much capacity to treat victims as possible. (Noji 1991, Noji 2005)

A recent example (September 2006) of the impacts of structural failure is the damage to the Kaaimans Bridge near George (in Eden, the neighbouring District Municipality) which was damaged to such an extent that the collapse of the bridge was a possibility. In the aftermath of the flood, the bridge was not fully operational for an extended period (trucks above 25 tons were not allowed access between 06h00 and 18h00). The impact on the economy of the region, a tourist paradise, is not fully quantified, but the town of Knysna were said to be losing about R80 000 per day in revenue at the time (pers comm. Pandaram 2006).

6.3.3 Economic measures

"Equitable economic development is the key to risk reduction" (Botha and Louw 2004). Risk reduction measures that increase the capacity of a community to cope with future economic losses help them withstand losses and improve their ability to recover. Economic development should be one of the main focuses of regional planning, and is a complex topic. Diversification is an extremely important economic principle as it reduces the risk by spreading it. A single crop or industry is more vulnerable than a farm or industry relying on different activities for an income. The tourism industry, for example, is considered an extremely vulnerable economic sector. Economic incentives and penalties, such as grants, loans and taxes can all be instrumental in influencing the decisions people make to reduce disaster risk. In the industrialised countries, insurance is one of the major economic protection measures. Insurance is however expensive and is determined by accurate calculation of risk.

6.3.4 Management and institutional measures

Procedural and organizational measures are very important in reducing risk. It is a longer term initiative than any of the other measures discussed here, and requires institutional-buy in. It includes a consensus of opinion amongst decision-makers that reducing risk is of continuous importance. Further, education, training, professional and technical competence and budget allocations are important. Kabat et al (2003) list the following examples:

- Zoning: regulation of building developments below flood lines and
- Budgeting for forecasting (early warning) systems, as well as evacuation and recovery.

6.3.5 Societal measures

The most important societal measure in reducing risk is that public awareness is created. A ‘safety culture’ should be cultivated, where the community reach consensus that risk reduction measures are desirable, feasible and affordable. Everyone living in a hazard-prone community should be aware, educated and capacitated to deal with the disaster should it occur, but also reduce the risks as part of every-day life. An example of this would be earthquake drills in schools, which create awareness and behavioural response during an incident. Societal measures in the health sector include, for example, creating an awareness of the health benefits of hygiene, maternal and child health and sex education for young adults.

6.4 Suggested risk reduction strategies

The future vulnerability of the population to the health impacts of climate change largely depends on the magnitude of the increase in potential health impacts and on our capacity to adapt to potential adverse changes through legislative, administrative, institutional, technological, planning educational and research-related measures. Two major strategies to reduce the health risk for the

Cape Winelands District under a future climate are suggested, each encompassing several interventions.

6.4.1 Strategy 1: The PREVENTION strategy

The focus of the first strategy, outlined in Table 27 is on ensuring the economic livelihood of the rural communities, including commercial farming, to increase socio-economic well-being and avoid poverty related disease. The strategy also addresses combating climate change. Although a global phenomenon, contributions towards mitigating change should start at a regional level. South Africa's carbon emissions have doubled between 1980 and 2004. South Africa is one of the highest emitters per capita globally (only slightly lower emissions than that of the UK which has 13 million more people) but has not been addressing it appropriately according to the South African Climate Action Group. (Cape Times 21/05/2007) Existing climate change-related activities, policies and programmes in the Western Cape are listed in Annexure C. National and international policies and conventions in Annexure Are summarised in Annexure D. Government is however still in the process of finalising strategies for mitigation.

This table illustrates the inter-sectoral and inter-departmental strategic approach. The role of the Disaster Management Centres (three spheres of government) is of utmost importance to coordinate and align these strategies with existing programmes and initiatives and to emphasize that solutions to future health risk should be addressed holistically.

6.4.2 Strategy 2: The CURE strategy

Strategy 2 is aimed at the poor in urban dwellings, and focuses on reducing their vulnerability to disease. It also addresses the environmental aspects (water quality) that results from their living conditions that can lead to an even higher disease incidence and impact on the fruit export industry. Recent press reports, quoting the Director-General of the Department of Water Affairs and Forestry, cautioned that roughly one third of South Africa's 1000 water treatment plants requires immediate intervention to avoid a crisis (Business Day 14/06/2007). Should the issue of poor water quality in the study area not be addressed, the direct impacts on health in the under-serviced communities will only worsen. The indirect impact on health, i.e. the poverty induced by a probable faltering agricultural sector, poses an even bigger threat.

Table 27: Suggested risk reduction strategy 1:'Prevention'.

1A: **Rural economy stimulation**	Reduce influx (migration) from rural populations employed in agriculture to towns/ cities (informal settlements) in search of alternative employment	• Research alternative crops suitable for a changed climate • Explore alternative sectors to agriculture • Empower farm labourers (skills development)	Department of Agriculture Department of Trade and Industry Department of Trade and Industry, Department of Education Non-governmental Organisations
1B: Reduce rapid urbanisation	Reduce Migration to Western Cape by mostly Eastern Cape population	• Stop migration (push-factors) of farm labourers and rural population to towns • Active buy-in from Eastern Cape and other Provincial role-players • Create employment opportunities in Eastern Cape and other provinces through economic development • Introduce and teach demographic principles, including family planning	National Disaster management Centre Department of Trade and Industry, Non-governmental Organisations National, Provincial and District Disaster management centre, Department of Health, Department of Education, NGO's.
1C: Combat climate change	Reduce greenhouse emissions and combat global change	• Implement and better Environmental education • Promoting a 'green' lifestyle • Complying with measures set out by the international and national authorities for compliance with the Kyoto protocol and providing greener alternatives through institutional measure	Department of Education Disaster management Department of Environmental Affairs District and Local Municipalities

Table 28: Suggested risk reduction strategy 2: 'Cure'

			Role-players
2A: **Urban municipal services**	To uplift the physical living conditions contributing to disease of the rural poor and informal settlement dwellers	• Improve Engineering service delivery (water and sanitation) • Provide low cost housing • Upgrade Waste-water treatment works • Monitor Water quality, specifically water for irrigation use • Implement Urban water demand management initiatives	Municipality Municipality, Provincial Government Municipality Municipality, Department of Water Affairs and Forestry Department of Water Affairs and Forestry, Department of Agriculture, City of Cape Town, District and Local Municipality, Provincial and District Disaster Management Centres
2B: **Poverty alleviation**	To alleviate poverty in urban settlements	• Create Employment opportunities • Provide Education and training	Department of Trade and Industry Department of Education, Social services, Department of Agriculture, Non-governmental organisations
2C: **Health care**	Improve and maintain services and standards of public sector service delivery to rural and urban poor and farming communities.	• Ensure adequate staff and facilities • Focus on preventative measures such as immunisation campaigns – specifically for TB • Focus on child and maternal health • Educate communities (specifically women) on basic health issues such as the role of sanitation and hygiene	Department of Health Municipality Department of Health, Disaster Management Centre Municipality Disaster Management Centre, Social Services Department of Education Municipality

The strategies illustrate that only a multi-sectoral approach can reduce the risk in the area. Health care measures form only part of the solution, and include issues such as:

- improved early warning systems
- improved disease surveillance and prevention programs
- improved sanitation systems
- education of health professionals and the public
- research addressing key knowledge gaps in climate/health relationships

Many of these adaptive responses are desirable from a public health perspective irrespective of climate change. For example, reducing air pollution obviously has both short and long-term health benefits. Improving warning systems for extreme weather events and eliminating existing combined sewer and storm water drainage systems are other measures that can ameliorate some of the potential adverse impacts of current climate extremes and of the possible impacts of climate change.

Improved disease surveillance, prevention systems and other public health infrastructure at the state and local levels are already needed. Adaptation is a complex undertaking as demonstrated.

The costs involved in implementing these strategies vary, and will have to be borne by different departments and even authorities. This can only be achieved through sound cooperative governance initiatives and inclusion into the District and Provincial Integrated Development Plan (IDP) the Spatial Development Frameworks and the municipal and provincial economic planning. Considerable work however still needs to be done to assess the feasibility (for example, the ability of a community/the district/the province to incur the costs) and the effectiveness of alternative adaptive responses and to develop improved mechanisms for coping with climate variability and change.

6.5 Risk reduction and the Integrated Development Plan

The Disaster management Act states that Disaster Management Plans must form an integral part of the Integrated Development Planning Process (Section 53, no 2(a)).

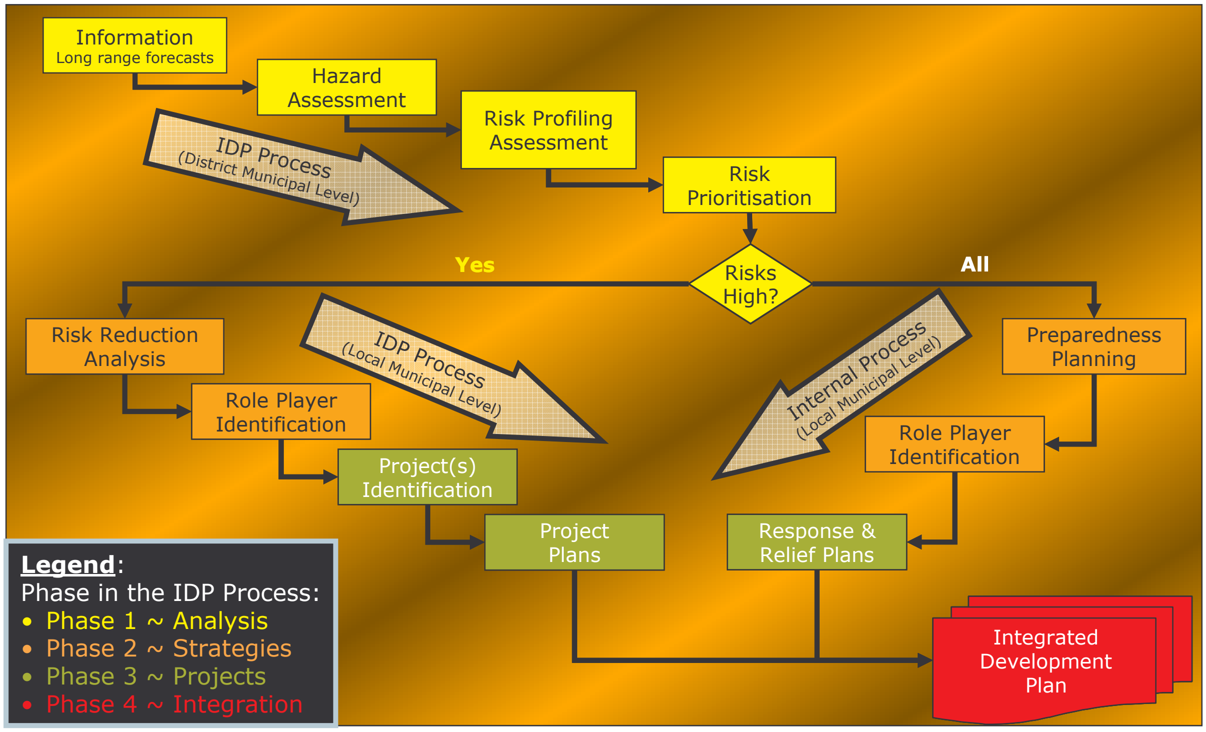

Figure 22: The disaster management planning process and its links with the Integrated Development Planning process.

Figure 22 illustrates the Disaster Management Planning process and the corresponding phases with the Integrated Development Planning process. (Refer to the discussion of the IDP in Chapter 3.) Once the strategies have been defined, specific projects must be identified and project plans must be drawn up, that have to be prioritised by the municipal management from a holistic and functional perspective.

The advantages of including the plans in the IDP are the following (Botha and Louw 2004):

Public Participation: Substantial public participation is required as part of both processes,

Potential Duplication: Both require analysis of the existing situation where there are overlaps in terms of the information that needs to be gathered and analysed,

Integration: The IDP plays a co-ordinating, facilitating and integrating function between the different sectoral plans and

Funding: Without inclusion into the IDP, disaster risk reduction projects will not be allocated with a budget and it will therefore not be possible to implement them.

6.6 Manageability, awareness and capacity building

The measures and strategies described in the previous section were traditionally not regarded as typical disaster management functions. Disaster management is still associated with response and recovery in many of the municipalities in South Africa, by role-players and other officials. This lack of understanding and knowledge was also illustrated by the discrepancies in the results of the questionnaires during the risk analysis for the Cape Winelands. The perceptions of hazards and risks were fairly limited which resulted in an exclusion of important hazards and a misinterpretation of the questionnaire. The traditional role of the disaster manager, focussing on a strong response paradigm, however resulted in well-prepared and efficient traditional preparedness (contingency) and recovery measures to deal with disasters such as floods, droughts and fire. It is this perception of disaster management and its sphere of influence that contributes to the lack of funding to implement strategies and a general naivety in terms of responsibilities and the more holistic view towards disaster management. A contributing factor to the lack of buy-in into measures concerning longer-term risks is the period of office of the official or councillor. A general feeling of 'not in my life-time' prevails, which results in inadequate budgets to deal with future disaster risk, i.e. the 'unseen'.

The apparent lack of understanding in the Cape Winelands was partly addressed by the development and presentation of a 2-day training course (Botha and Louw 2005) to officials from the five local municipalities in Worcester on 5 and 6 April 2005. The learners included disaster management officials, councillors and officials from departments such as health, housing, engineering services and environment. The course included the following modules:

- Putting disaster management into perspective
- Definitions and terminology
- Legal requirements
- Establishment of Disaster Management Centres
- Disaster Risk Assessment
- Disaster Risk Reduction Plans

- Disaster Preparedness Plans
- Disaster Impact Assessments
- Overview of Disaster management Information systems

Initially, participants, specifically those from non-traditional disaster management spheres such as housing and education were sceptical about the applicability to their field. The course, however, succeeded in explaining the inter-departmental, inter-sectoral approach to disaster management and their contribution towards risk reduction. (The course has since been presented to other districts, and has been provisionally accepted for accreditation by SETA.)

6.7 Current risk reduction initiatives

Since the conclusion of the disaster risk assessment, a task team with role-players from the district, farmers, academics and the Department of Water Affairs have been established to address the water quality problem. This was an initiative by the Environmental Department of the Cape Winelands district and is promising, as the problem was at long last acknowledged. Currently it has however not manifested in an improved water quality. Hopefully this indicates the start of an inter-departmental cooperative milieu that will continue to address this issue with also be able to address other risks in such a manner.

Specific recommendations addressing the identified vulnerabilities and risks will be made in the next chapter.

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CHAPTER 7

Conclusions, recommendations and synthesis

7.1 Conclusions

The earth's climate systems have demonstrably changed on both global and regional scales since the pre-industrial era. The 1990's was the warmest decade in the instrumental record since 1861. There is new and stronger evidence that most warming observed over the last 50 years is attributable to human activities. Climate change implies that the earth's biophysical and ecological systems are altering. These changes are predicted to manifest as, inter alia, more frequent and severe weather events, increases in temperature in many regions and resulting changes in precipitation patterns.

Health largely depends on the efficient functioning of ecosystems, for example the availability of safe drinking water, sufficient food and shelter. The impacts of climate change on health were previously neglected in local and international assessment and mitigation reports. Specific impacts at regional level have not yet been determined in depth or with narrow margins of uncertainty. The health outcomes that are theoretically acknowledged to be associated with climate change are mostly illnesses and deaths associated with temperature, extreme precipitation events, air pollution, water contamination and disease carried by mosquitoes, ticks and rodents.

In South Africa, following international best practice, there is an increased paradigm shift towards risk reduction which is formulised in the Disaster Management Act (Act 57 of 2002) that instructs the provincial and municipal spheres of government to conduct scientific disaster risk assessments to determine disaster risk. The impact of climate change poses a major and largely unfamiliar threat that must be investigated when conducting a disaster risk assessment to enable the implementation of appropriate risk reduction strategies. Such a study was conducted for the Cape Winelands District Municipality, with specific reference of the impact of climate change on human health.

It was found in this study that the Cape Winelands District Municipality is characterised by a population that is predominated by young females and that is largely illiterate and unskilled. Eighty-six percent of the 629 490 inhabitants live in relative or seasonal poverty. The agricultural sector provides employment to 38% of the population. The health profile of the inhabitants of the Cape Winelands District Municipality is below optimal. The epidemiological health assessment points to a population primarily affected by poverty-related disease and who are living in a polluted environment, exposed to contaminated water and poor sanitation.

The results of the scientific risk assessment for the region highlighted flooding, fires, drought, road accidents, earthquake risk and biological risk associated with environmental degradation as the major existing threats. Climate change has been found to potentially exacerbate the occurrence of each of these hazards, except earthquake risk, which is not directly related to climate. The resulting impacts on health include inter-alia trauma injury, water-related disease and airborne infections. When assessing risk, the vulnerabilities must however also be assessed. Climate change also poses a potential major threat to the agricultural sector, a so-called economic vulnerability, with resulting secondary impacts on health. It is concluded that the major threat of climate change on human health is a result of the high societal en economical vulnerability of the area which will manifest as water-related and poverty-related disease. This is a typical example of a slow-onset disaster that requires urgent inter-departmental and inter-sectoral risk-reduction initiatives.

Disaster management in the area still focuses largely on response and recovery and can barely cope with the current conditions. Health care services are not meeting targets and are unlikely to cope with any aggravating circumstance. Climate change proved to be a major potential threat to human health in the district and, if not addressed, may sooner or later result in a full-fledged disaster scenario.

The qualitative hypothesis was constructed (Chapter 1) that the status of the existing vulnerabilities in the Cape Winelands District Municipality is such that climate change (seen as an added stressor), will compromise the district’s ability to cope and aggravate future disaster risk. In light of the above it can therefore be concluded that this hypothesis has been confirmed.

7.2 Recommendations

7.2.1 Recommended actions for the Cape Winelands District Municipality

7.2.1.1 Water-related issues

It is imperative that the existing pressure on the water resources in the area is lessened to protect the resource. The probability that future changes in climate can bring more prolonged droughts in its wake is very real and the present freshwater resources are already under strain. The region already has to 'import' water for its needs by transfers from ever more distant sources (thereby depleting the surroundings of those sources of water). Water resource planning should be undertaken with due input from agriculture, industry, health services, disaster management and all sectors of the community (to name a few of the important role players).

At present the Department of Water Affairs and Forestry (DWAF) is engaged in the formation of a Berg Catchment Management Agency (CMA) that is supposed to take over much of the day-to-day running of the 'water affairs' of this region. This has the potential to be even more problematic from a planning and emergency perspective. The CMA has a crucial role to play in guarding the safety of water supplies and distribution networks. The lack of clarity about exactly who is to take action in undesirable situations before they reach crisis proportions is unclear. This concern goes for both slowly deteriorating quality aspects such as the CWDM are already experiencing and the acute disasters of dramatic pollution that can happen unexpectedly.

The dividing line between the duties and responsibilities of DWAF on the one hand and the CMA on the other is unclear and provides for unfortunate shuttling of effective action between the two organs of state. This bears all the hallmarks of yet another source of stalling of effective and timely action.

At present the motivation for action on water pollution and water resource planning are driven from an economic perspective, since the driving forces have originated mainly in the agricultural sector, and particularly in the export section of that sector. This approach however, fails to consider some very important imperatives outside the direct scope of the economy, but that would impact heavily on the economy. Some of these imperatives are the health aspects and disaster planning aspects that receive scant attention at the present.

As an example of the health aspects that could seriously upset the planning and implementation of remedial action and that could force massive short-term emergency intervention, is the outbreak of a waterborne disease such as typhoid in the catchment of the Berg River. There have already been two cases of typhoid on farms close to the river in the Wellington area towards the end of 2006, which fortunately could be treated and the escape of the organism into the environment could be prevented. With the continuing entry of massive loads of untreated sewage into the Berg River, the region may not be so fortunate next time. A full-scale outbreak of waterborne disease is almost inevitable sooner or later if the situation continues as it is now. Such an outbreak can turn the whole present (economically driven) approach on its head. The almost complete lack of short-term emergency interventions of DWAF is therefore of great concern. In fact, the health impacts of the present crisis seem to have been virtually disregarded at present.

The same remark regarding the short-term emergency nature of the present situation in and around the Berg River goes for lack of plans for coping with disasters such as earthquakes and floods (which can damage infrastructure and release massive pollution in the form of untreated sewage) or even droughts (which can exacerbate the pollution load in the remaining water in the rivers).

The immediate improvement of water and sanitation service delivery to informal settlements should receive much more urgent attention. The delivery of such services is coupled to orderly and practical housing and urban settlement policies that are upheld by all political and local authority structures. Alternative methods of sanitation should be investigated in order to lessen the demand on water used by waterborne sewerage systems. The housing of informal settlement communities – coupled with the proper services – will uplift the living conditions that contribute so greatly to infectious disease prevalence. The other waste streams such as solid waste and polluted stormwater run-off in urban areas are other issues needing urgent attention.

The capacity of local authorities to cope with waste in all its forms should be improved as a matter of the utmost urgency. The sewage treatment works in virtually all the urban areas in the region are facing daily loads that exceed their capacity. The sewerage systems in all the towns in the region are old and in urgent need of upgrading and even just proper repair and maintenance. These are just some examples that need to be put on the table in a holistic planning exercise for the region that is at present not happening. Any improvements in the lives of, for instance, the inhabitants of informal settlements, will not only improve their ability to cope with potential adverse events associated with climate change, but will be of immediate benefit to the whole region.

7.2.1.2 Health issues

Public health services on all levels in the areas must be maintained and strengthened to address preventable disease associated with socio-economic status of a population. The low cure rate of TB is of great concern and the capacity of the health services to cope with the present case load should receive the attention of the provincial health authorities. Unfortunately the province as a whole is engaged in a series of budget cutbacks that could compromise the present levels of staffing and facilities even further. This is in direct opposition to the needs of the area, and will worsen any ability to cope with adverse events (acute or slow) that could arise from possible future climate change.

7.2.1.3 Agricultural issues

The district should also actively seek to find solutions to the threat of climate change on agriculture. The agricultural industry should start to explore alternative crops or alternative sectoral employment for the portion of the population employed in the sector that may lose their jobs in adverse situations without delay.

Although organised agriculture has for some years been engaged in reducing their dependence on copious supplies of cheap water, these initiatives should be extended to informal and small-scale farmers who usually lack the infrastructure and capital to benefit from these initiatives. This should be addressed.

The social conditions facing a large sector of the population engaged in the agricultural industry are conducive to lifestyle problems accompanying poverty, alcohol misuse and foetal alcohol syndrome, poor nutrition. Upliftment of this sector of the population in various ways should be properly planned for on a region-wide scale and driven by real commitment. At present only a few non-governmental organisations and a few social services are engaged in a task too large for them to make a meaningful difference. The resultant improvement in disease profiles, crime and under-productivity would be of benefit to everybody in the region.

7.2.1.4 Local governance issues

The skills and capacity of officials on municipal level must be actively addressed to enable inter-sectoral involvement and decision-making to fulfil the role of disaster risk management stipulated in the Act.

Decision-making and risk reduction can however only be based on reliable data to determine targets and monitor progress. The district should insist that the public health authorities, as well as the agricultural sector, collect appropriate data to achieve this.

7.2.2 Recommendation for further research

The disaster management field, as instructed by the recent paradigm shift from response and recovery to risk reduction, holds enormous potential to conduct analyses on appropriate spatial and conceptual scales. Climate change adds the previously neglected dimension of time, which, as shown in this research, cannot be ignored. Although the link between climate and disasters have been recognised by several studies and listed the focus has been on the direct impact of natural disasters (and climate change induced hazards) on health. The following research areas should be focussed on in the South African context:

7.2.2.1 Health

Health has emerged as a major impact of climate change, and has thus far in Southern Africa as in many other countries, not been addressed accordingly. The research into empirical relationships between disease (specifically vector-borne disease) and weather seems to be prevalent in this field and should continue. It is however imperative that conclusions of the resulting impact is drawn in a real-world scenario. This entails assessing vulnerabilities and pre-existing health profiles. However, to enable the quantification of health risk under a changed climate, substantial data sets are required (see chapter 4). Current health status is difficult to assess due to a lack of data. To increase coping mechanisms, health sector and related planning is required, which is only possible with supporting statistics. In terms of general research, more focus should be placed on the indirect impacts, and relatively less emphasis on the obvious relationships between weather extremes and health.

7.2.2.2 Risk Assessments

The candidate recommends that risk assessments within the South African context should include the threat of climate change, as many impacts require medium to longer term risk reduction initiatives. It is highly recommended that the impact of an external trigger such as climate change, be studied within the context of disaster management, as it presents itself as a holistic tool to fully assess the impacts thereof. The case study assessed vulnerability ***qualitatively***, and to a certain extent using the 'exposure' parameter, as described in chapter 3, as indicator when assessing total risk. This research however illustrates the importance the vulnerability in the risk equation and suggests an increased attempt to quantify vulnerability to enable a more accurate risk assessment. Since the case study, the Risk Assessment methodology has been substantially refined to enable ***quantification of vulnerabilities***. A discussion is however not included here. The parameters used to measure vulnerability should constantly be revised and explored in an attempt to 'measuring the unmeasurable'. The challenge is however to obtain reliable to data for each of these parameters.

7.2.2.3 Climate Change

Ongoing research in the regional impacts of climate change is recommended, specifically with regards to the Southern Hemisphere and the Western Cape. The uncertainties in regional forecasts create difficulty when assessing impacts of climate change in any sector, and research should thus be encouraged to enable more reliable predictions.

7.3 Synopsis and Synthesis

The study examined the impact of probable changes in climate on disaster management aspects and human health in the Cape Winelands District Municipality

This study encompassed many different disciplines (disaster management theory, health, agricultural economy and climate), and illustrated the importance of holistic, conceptual thinking when assessing and addressing disaster risk. The issues and problems occurring in the real world are intersectoral and interdisciplinary. On the other hand, research tends to be discipline-specific and its endpoints narrowly and rigidly defined. The challenges to assess the impact of climate change on health require insight into and data on many different subjects and many parameters respectively. The actual problems occurring in the region cannot be approached as an "extended research project" since the interrelated nature of the problems makes narrow inclusion and exclusion criteria employed by research too far removed from reality to provide valid answers. In order to assess the real extent of existing problems and make meaningful predictions for the future, reliable and detailed data are needed. The status of official figures on almost all aspects of health, infrastructure and risk factors were poor and that hampered deeper analysis considerably. Planning should, however, not be postponed until better information is available, since the welfare of the whole region depends on timely action.

Climate change will inevitably occur sooner or later and the health implications for the district with its high economic vulnerability proved to be substantial. Disaster Risk Management initiatives must be taken seriously and capacity must be developed to ensure pro-active governance.

The cost of inaction will be immense.

Annexure A

A1. Letter of invitation to Disaster Management Advisory Forum

Members of the Advisory Forum: Disaster Management and other disaster management role-players
c/o Cape Winelands District Municipality
PO Box 100
Stellenbosch
7599

Dear Sir/Madam

Invitation to attend the first workshop: Disaster risk and vulnerability assessment

AFRICON won the tender to conduct a disaster risk and vulnerability assessment for the Cape Winelands district municipality in January 2005. You are cordially invited to attend the first workshop of this project to be held at the Council Chambers of the Cape Winelands District Municipality in Trappe Street, Worcester from 09h00 to 13h00 on the 10th of March 2005.

Background:

South Africa is prone to a variety of natural and human-induced disasters, which occasionally lead to loss of property and lives. In the past decade, these hazard occurrences have become more frequent and severe. The National Government recognized a need for an institutional framework that allows for disaster risk prevention and rapid action during an occurrence and has taken certain steps towards this end, such as:

- **White Paper on Disaster Management**: the white paper introduced a new paradigm in the management of disasters, by placing emphasis on risk reduction and preparedness
- **Disaster Management Act**: The white paper lead to the promulgation of the Disaster Management Act, Act 57 of 2002, which is the regulatory framework for disaster management in South Africa.
- **The National Disaster Management Framework**: The NDMC has recently published the first draft of a National Disaster Management Framework, which aims to guide the development and implementation of disaster management in the country.

According to the Act (section 53), a district Municipality must compile disaster management plans for their area of jurisdiction. Specifically they must:

(a) prepare a disaster management plan for its area

(b) co-ordinate and align the implementation of its plan with those of other organs of state and institutional role-players

(c) regularly review and update its plan

(d) through appropriate mechanisms, processes and procedures consult the local community on the preparation or amendment of its plan.

A district municipality and the local municipalities within the area of the district municipality must prepare their disaster management plans after consulting each other

Disaster Risk and Vulnerability Assessment

A Disaster Risk and Vulnerability Assessment is the first step towards compilation of a disaster management plan. Successful completion of this project is highly dependant on the cooperation of all the role-players in Disaster Management in the District Municipality. The purpose of this first workshop is to introduce the project and explain the methodology to be followed. Specific attention will be given to the inputs and cooperation required from role-players.

As we value your inputs, we request that you attend the above-mentioned workshop to ensure an effective consultative process and a quality end-result. Please RSVP to Sonica Koopman on telephone number 021 888 5163 no later than 8 March 2005.

Yours sincerely

A2. List of 2005 Cape Winelands Disaster Management Advisory Forum Members

NAME and SURNAME	POSITION	COMPANY	POSTAL ADRESS	E-MAIL	TEL(W)	CELL	FAX
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		Commando	WORCESTER, 6849				
MR. S ARANGIE	Delegate	Cape Winelands District	PO Box 100	stoffel@bolanddm.co.za	021-888 5173		
		Municipality	STELLENBOSCH, 7599				
MR M SWARTLAND	Secundi	Cape Winelands District	PO Box 100	marius@bolanddm.co.za	021-888 5175		
		Municipality	STELLENBOSCH, 7599	-			
MR. D. WILDS	Fire Services	Cape Winelands District	PO Box 100		021-888 5306	082-822 1233	021-886 6206
		Municipality	STELLENBOSCH, 7599				
CJE LEANDER	Counicillor	Cape Winelands District	PO Box 100	chris@bolanddm.co.za		082 459 8344	
		Municipality	STELLENBOSC	-			

NAME and SURNAME	POSITION	COMPANY	POSTAL ADRESS	E-MAIL	TEL(W)	CELL	FAX
			H, 7599				
MRS. A. SNYMAN	Planning Services	Cape Winelands District	PO Box 100		021-888 5194		021-882 8190
		Municipality	STELLENBOSCH, 7599				
DR. M LE CORDEUR	Circuit Manager	WC Education	Private Bag X3026	-	021-887 0222		021-887 0240
		Department	PAARL, 7620		021-887 0235		
MR CJ DE VILLIERS		District RDS	PO Box 1	cjdevill@pgwc.gov.za	021-863 2020	082-906 2813	
		Engineer	PAARL, 7620				
P. ELLIS		District RDS	PO Box 1	pellis@pgwc.gov.za	021-863 2020	082-906 2820	
		Engineer	PAARL, 7620				
MR. R. MAIR	Major	The Salvation	PO. Box 5	-	021-884 4598	082-773 3911	021-884 4602
		Army	ELSENBURG, 7607				
MR. P. GIBBONS	Disaster Relief	The Salvation	PO. Box 5	pjgibbons@mweb.co.za	021-884 4600	083-713 0890	021-884 4602
	Co-Ordinator	Army	ELSENBURG, 7607				
MR. B. SCHWARTZ	Major	The Salvation	PO. Box 5		021-884 4602	082-623 5560	021-884 4604
		Army	ELSENBURG, 7607	-			
MRS. A. LOOTS		Dept Agriculture	P/Bag X1	annamariel@elsenburg.co.	021-808 5140	083-642 0608	021-808 5120

NAME and SURNAME	POSITION	COMPANY	POSTAL ADRESS	E-MAIL	TEL(W)	CELL	FAX
				za			
			ELSENBURG, 7607	-			
MISS. R. THAVAR		Dept Agriculture	P/Bag X1	rthavar@elsenburg.com	021-808 5276	082-884 4361	021-808 5122
			ELSENBURG, 7607	-			
MR. W GROBBELAAR		Agri Western-Cape	PO Box 9001	grobbmod@intekom.co.za	021-962 1388	082-789 9198	021-962 1388
			KLEIN DRAKENSTEIN				
			7628				
MR. A DU TOIT		Agri Western-Cape	PO Box 83		023-342 1304	082-578 1569	023-342 1304
			WORCESTER, 6850				
MR. M.M. JAM		Dep. Correctional	P/Bag X 3057	Mandla.Jam@dcs.gov.za	023-347 2741		023-347 4550
		Services	Worcester, 6849		X 2203		
MR. V.W. KOLI		Dep. Correctional	P/Bag X 3057	Vuyisele.Koli@dcs.gov.z a	023-347 2743		023-347 4552
		Services	Worcester, 6849		X 2219		
MS KIM KLINE		Local Government	P/Bag X9076	kkline@pgwc.gov.za	021-483 2372		021-483 5015
			Cape Town, 8000				
MS.M. MURRIS	Director	Local Government			021-483 2372		021-483 5015

NAME and SURNAME	POSITION	COMPANY	POSTAL ADRESS	E-MAIL	TEL(W)	CELL	FAX
MR.S CARSTENS	Deputy Director	Local Government			021-483 2373		021-483 5015
MR E. KEET		Allendale Correctional	P/Bag X23, Dal Josafat		021-877 5741	082-569 8513	021-862 6857
		Services	Paarl, 7646				
MR. V. DE WET		Allendale Correctional	P/Bag X23, Dal Josafat		021-877 5757	082-707 9157	021-862 6857
		Services	Paarl, 7646				
MS. J. BRITS		Dept Home Affairs	P/Bag X 028	juanita.britz@dha.gov.za	021-872 3031		021-872 4246
			Paarl, 7646	-			
MS. PNR DEKEZA		Dept Home Affairs	P/Bag X 028	paarl@dbs1.pwv.gov.za	021-872 3032		021-872 4212
			Paarl, 7646	-			
H.H. SPANGENBERG		Dept Home Affairs	P/Bag X3081	Doworcester@dbs1.pgwc.gov.za	023-3425280/1/2/3		023-342 5284
			Worcester, 6849				
JH EHLERS	Secundi	Dept Home Affairs	P/Bag X3081	Doworcester@dbs1.pgwc.gov.za	023-3425280/1/2/3		023-342 5284
			Worcester, 6849				
LOUIS TITUS		Prov Traffic		lgtitus@pgwc.gov.za	021-9811161		021-9815888
MR MAC-IVAN ERASMUS	Delegate	Dept Transport and Public Works	District Road Engineer	macerasm@pgwc.gov.za	023-312 1120	082 906 2533	023-312 2633
			P/Bag X 2,	-			

NAME and SURNAME	POSITION	COMPANY	POSTAL ADRESS	E-MAIL	TEL(W)	CELL	FAX
			Ceres, 6835				
MR JAPIE ETSEBETH	Secundi	Dept Transport and Public Works	District Road Engineer	jetsebeth@pgwc.gov.za	023-312 1120	082 801 3955	023-312 2633
			P/Bag X2, Ceres, 6835	-			
DYREL		VCSV		vcsv.co.za			
DAWN		VCSV					
HM BUSHBY		Dept Comm Safety	P/Bag X3069		023-342 2357/8	082 8200620	023-347 4579
			Worcester, 6849				
CJ VOLSHENK	Secundi	Dept Comm Safety	P/Bag X3069				
			Worcester, 6849		023-342 2357/8	083 2308187	023-347 4579
B – MUNICIPALITIES (local municipalities)							
D DAMON	Chief: Fire Service	Drakenstein Municipality	PO Box 1	derick@drakenstein.gov.za	021-872 1404	082 415 9342	021-872 0468
			Paarl, 7620				
D PEKEUR	Deputy Chief		PO Box 1				
	Fire Services	Drakenstein Municipality	Paarl, 7620	dereck@drakenstein.gov.za	021-872 1404	082 417 2232	021-872 0468
NICO NEL	Municipal Manager	Breërivier/Winelands	P/Bag X 2	-	023-615 8000		023-615 1563
		Municipality	Ashton, 6715	-			
J DURAND	Manager: Fire	Breërivier/Winelands	P/Bag X2	jandurand@telkomsa.net	023-626 2089	083 320 1073	023 626 2022

NAME and SURNAME	POSITION	COMPANY	POSTAL ADRESS	E-MAIL	TEL(W)	CELL	FAX
	Service						
		Municipality	Ashton, 6715				
J TRISKEY	Acting Disaster Manager	Breedevalley Municipality	P/Bag X3046	jtriskey@breedevallei.gov .za	023-342 2431	082 876 9228	023-347 1653
			Worcester, 6849				
P GOVENDER	Chief Fire Officer	Breedevalley Municipality	P/Bag X3046	sfox@breedevallei.gov.za	023-342 2431	083 790 1007	023-347 1653
			Worcester, 6849				
FRANK DANIELS	Manager: Traffic	Witzenberg Municipality	PO Box 44, Ceres,6835	frank@witzenberg.gov.za	023-316 1997/8	082 217 4630	
H ELS	Protection Officer	Witzenberg Municipality	PO Box 44, Ceres,6835	traf@witzenberg.gov.za	023-316 1997	082 568 6486	023 316 1998
JACOBUS DAVIDS	Hoof; Gedeelde Dienste	Stellenbosch Municipality	PO Box 17	kobus@stellenbosch.org	021-808 8900	084 458 4510	021 808 8919
			STELLENBOSCH, 7599	-			
LUCINDA VAN KEWEL	Disaster Management	Stellenbosch Municipality	PO Box 17		021-808 8900	082 810 9913	021 808 8919
	Officer		STELLENBOSCH, 7599				

Annexure B

Risk Assessment Questionnaires
B1: Risk Assessment Guidelines

Guidelines to Risk Identification, Prioritisation and Manageability

1. Risk Identification

The following needs to be completed for Risk Identification:

- **A set of checklists:** There are four different checklists. They would include ones for natural, technological, biological and environmental hazards.
- **A set of tables:** These tables will relate to a specific hazard. As the checklist is being completed, a separate table is drawn up to list the incidents that have occurred relating to a particular hazard.

Let's work through an example. The **checklist** for Natural Hazards is similar to the figure to the left. For example floods, fires and storm surges could have occurred in the area.


Checklist
Natural Hazards

- [x] Floods
- [x] Fires
- [ ] Drought
- [ ] Earthquakes
- [ ] Landslides
- [ ] Mudflows
- [x] Storm Surges
- [ ] Hail Storms
- [ ] Severe Storms
- [ ] Hurricane/Cyclone

Once this has been done, an incident **table** is completed for each of the hazards that were ticked off. As in our example, a table is completed for floods and fires and other hazards marked off. For each hazard, actual events that have occurred are listed with information on where, when, how many deaths and injuries and the estimated losses (this information many not be available).

Flood

Location	Date (Duration)	Deaths	Injuries	Estimated Losses
Nelspruit	4 January to 10 January 2020	7	15	R 150 000
Ermelo	1 March 2020	2	20	R15000

Fire

Location	Date (Duration)	Deaths	Injuries	Estimated Losses
Pretoria	24 July to 26 July 2020	2	4	R 50 000
Rustenburg	19 May 2020	10	20	R100 000

2. Risk Prioritisation:

The following needs to be completed for Risk Identification:

Exposure: You must assess the exposure of communities in your region to each of the hazards and classify their exposure into one of three categories.

- **Continuous:** Should a community be continuously exposed to a hazard, such as, an informal settlement situated adjacent to a toxic waste site, they will be continuously exposed to the hazard (polluted air, polluted ground water, etc.).
- **Occasional:** When a community is occasionally exposed to a hazard, such as an informal settlement situated in a flood plain ~ they will only be exposed occasionally to a flood occurrence.
- **Seldom**: Communities that are seldom exposed to a hazard will not be vulnerable to that hazard.

Probability: You must assess what is the probability, or likelihood, of a hazard occurring and classify it into one of three categories.

- **Likely:** Hazards in this category will have a very high probability of occurring (>75%).
- **Normal:** Hazards in this category will have a normal probability of occurring (50%).
- **Unlikely:** Hazards in this category will have an unlikely probability of occurring (<25%).

Severity: You must assess the severity, or impact, or magnitude, of the hazard, should it occur, and classify it into one of three categories.

- **Extreme:** Hazards in this category will hold extreme consequences to a region, such as, an earthquake within the City of Cape Town.
- **Moderate:** Hazards in this category will hold moderate consequences to a region
- **Insignificant:** hazards in this category will hold insignificant consequences to a region.

Please check (√) in the appropriate box to rate whether a hazard's exposure is continuous, occasional or seldom, the probability is likely, normal or unlikely or the severity is extreme, moderate or insignificant.

Flood

Exposure	Continuous	√	Occasional		Seldom	
Probability	Likely		Normal	√	Unlikely	
Severity	Extreme	√	Moderate		Insignificant	

Fire

Exposure	Continuous		Occasional	√	Seldom	
Probability	Likely		Normal		Unlikely	√
Severity	Extreme		Moderate		Insignificant	√

3. Risk Manageability:

Quantify Risk Manageability: The degree to which a community can intervene and manage the negative consequences of a hazard event will depend on the following:

- **Awareness:** The over-all awareness of people living in a potential impact area of a hazard to that hazard is one of the factors that determine the risk manageability of a community

- **Legislative Framework:** The legislative framework that governs a particular hazard event is one of the factors that determine the risk manageability of a community.
- **Early Warning Systems**: Rate the early warning system for a hazard event.
- **Government Response:** The nature of government's response
- **Government Resources:** Rate the resources available to your municipality and the provincial government for a hazard event on a three point scale.
- **Existing Risk Reduction Measures:** Rate the existing risk reduction measures of the municipality and the provincial government to a hazard event.
- **Public Participation Measures:** Rate the existing public participation measures of the municipality and the provincial government to a hazard event.
- **Municipal Management Capabilities:** Rate the over-all management capability of the municipality for a hazard event.

Please check (√) in the appropriate box to rate the degree to which your municipality can intervene and manage the negative consequence of a hazard event.

Flood

	Good	Modest	Poor
Awareness			√
Legislative Framework			√
Early Warning Systems		√	
Government Response	√		
Government Resources		√	
Existing Risk Reduction Measures			√
Public Participation Measures	√		
Municipal Management Capabilities	√		

Fire

	Good	Modest	Poor
Awareness	√		
Legislative Framework		√	
Early Warning Systems		√	
Government Response	√		
Government Resources	√		
Existing Risk Reduction Measures	√		
Public Participation Measures		√	
Municipal Management Capabilities			√

B2: Hazard identification checklist

Completed by: Organisation:
Telephone No:

<u>Checklist: Natural Hazards</u>

Hydro-meteorological

- [ ] Cyclones
- [ ] Drought
- [ ] Fires
- [ ] Floods
- [ ] Hail Storms
- [ ] Hurricanes
- [ ] Severe Storms
- [ ] Storm Surges
- [ ] Wind
- [ ] Other
  Specify:

Geological

- [ ] Earthquakes
- [ ] Landslides
- [ ] Mudflows

Completed by: Organisation:
Telephone No:

<u>Checklist: Technological Hazards</u>

- [ ] Dam Failures
- [ ] Hazardous installations
- [ ] Hazardous Materials Accidents by Road
- [ ] Hazardous Materials Accidents by Rail
- [ ] Aircraft Accidents
- [ ] Other
  Specify:

<u>Checklist: Environmetal Hazards</u>

- [ ] Air Pollution
- [ ] Water Pollution
- [ ] Land Degradation
- [ ] Deforestation
- [ ] Desertification
- [ ] Other
  Specify:

Completed by: Organisation:
Telephone No:

Checklist: Natural Hazards (cont)

Biological Hazards

Human Diseases

- ☐ Anthrax
- ☐ Bilharzia
- ☐ Cholera
- ☐ Diphtheria
- ☐ Food Poisoning
- ☐ Foot-and-Mouth Disease
- ☐ Haemorrhagic Fever
- ☐ Legionellosis
- ☐ Malaria
- ☐ Measles
- ☐ Meningococcal / Meningitis
- ☐ Plague
- ☐ Polio
- ☐ Rabies
- ☐ Shigella Dysentry
- ☐ Tuberculosis
- ☐ Typhoid
- ☐ Typhus Fever
- ☐ Other
  Specify:

Animal Diseases

- ☐ African Horse Sickness
- ☐ Avian Influenza
- ☐ Bluetongue
- ☐ Botulism
- ☐ Food-and-mouth
- ☐ Porcine Reproductive and Respiratory Syndrome
- ☐ Rabies
- ☐ Rinderpest
- ☐ Tick-Borne Diseases
- ☐ Tsetse Flies-Tryponosamiasis

B3: Example of completed incident list

Type of Hazard: Natural **Completed by:**
Organisation: **Telephone No:**

Hazard Type	Location	Date	Deaths	Injuries	Type of Damage
Flood	"Laingsburg Flood" Montagu, Robertson, Ashton	1981-01-25	13	several	Robertson SAPS, Court buildings Railway Station. Massive power failure and infrastructure damage, agricultural losses. Montagu Springs Hotel destroyed.
Bushfire	Langeberg Mountain, Montagu.	1997-12-29			Langeberg mountain. 800 Ha mountain veld and vinyards destroyed.
Strucural Fire	Robertson	2000-09-24			Happy Valley. 8 X Thatch roof houses destroyed. 30 People relocated
Flood	Montagu	2003/03/24			2500 Occupants evacuated. Cogmanskloof pass closed for 12 days. Major agricultural losses, major dam failure, disruption of schools and factories, secondary road infrastructure damages
Flood	Robertson/Mcgregor	2004-12-23			Severe cloudburst lasting 4 hours causing serious disruption to services, inhabitants and businesses. 35 Families evacuated. Damage to municipal infrastructure.

B4: First page of risk prioritisation questionnaire

………………………….District Municipality

………………………….Local Municipality

Risk Prioritisation:

Please check (√) in the appropriate box to rate whether a hazard's exposure is continuous, occasional or seldom, the probability is likely, normal or unlikely or the severity is extreme, moderate or insignificant.

Natural Hazards

Cyclones

Exposure	Continuous		Occasional		Seldom	
Probability	Likely		Normal		Unlikely	
Severity	Extreme		Moderate		Insignificant	

Drought

Exposure	Continuous		Occasional		Seldom	
Probability	Likely		Normal		Unlikely	
Severity	Extreme		Moderate		Insignificant	

Earthquakes

Exposure	Continuous		Occasional		Seldom	
Probability	Likely		Normal		Unlikely	
Severity	Extreme		Moderate		Insignificant	

Fires

Exposure	Continuous		Occasional		Seldom	
Probability	Likely		Normal		Unlikely	
Severity	Extreme		Moderate		Insignificant	

Floods

Exposure	Continuous		Occasional		Seldom	
Probability	Likely		Normal		Unlikely	
Severity	Extreme		Moderate		Insignificant	

Hail Storm

Exposure	Continuous		Occasional		Seldom	
Probability	Likely		Normal		Unlikely	
Severity	Extreme		Moderate		Insignificant	

Hurricanes

Exposure	Continuous		Occasional		Seldom	
Probability	Likely		Normal		Unlikely	
Severity	Extreme		Moderate		Insignificant	

B5: First page of risk manageability questionnaire

……………………..District Municipality

……………………..Local Municipality

Quantify Risk Manageability: The degree to which a community can intervene and manage the negative consequences of a hazard event will depend on the following:

Please check (√) in the appropriate box to rate the degree to which your municipality can intervene and manage the negative consequence of a hazard event.

Natural Hazards

Hydro-meteorlogical

Cyclones

	Good	Modest	Poor
Awareness			
Legislative Framework			
Early Warning Systems			
Government Response			
Government Resources			
Existing Risk Reduction Measures			
Public Participation Measures			
Municipal Management Capabilities			

Drought

	Good	Modest	Poor
Awareness			
Legislative Framework			
Early Warning Systems			
Government Response			
Government Resources			
Existing Risk Reduction Measures			
Public Participation Measures			
Municipal Management Capabilities			

Fires

	Good	Modest	Poor
Awareness			
Legislative Framework			
Early Warning Systems			
Government Response			
Government Resources			
Existing Risk Reduction Measures			
Public Participation Measures			
Municipal Management Capabilities			

Annexure C

Existing Climate Change-related Activities, Policies and Programmes in the Western Cape

As summarised by Midgley et al (2005)

"…..**Government**:

The government of the Western Cape is currently considering a carbon tax, mainly to boost revenue streams (Business Day, 9 March 2005). Government policies, such as carbon taxes may impact on the cost of production and consumption and need to be researched for their environmental effectiveness as well.

The National Response Strategy to Climate Change, released in October 2004 will have implications on provincial level as well. The National DEAT will, where appropriate, enlist the cooperation of other government departments, provincial and local government and non-government entities. The document states that "certain provincial governments are already officially represented at the NCCC and the further involvement of provincial and local government in climate change matters should be actively solicited".

The City of Cape Town is involved in the Cities for Climate Protection Project. The city progressed from completing the greenhouse gas inventory for Cape Town to launching the CCP Campaign locally through an awareness programme and initiating a number of pilot projects to reduce emissions from City of Cape Town operations. They are investing in retrofitting energy-saving light bulbs in municipal buildings and informal settlement housing, bicycle feasibility study and exploring options such as encouraging household resource efficiency.

The City of Cape Town's Draft Air Quality Management Plan (AQMP) is being presently subjected to public review. The new national Air Quality Act of 2005 (to replace the Air Pollution Act no 45 of 1965) has yet to be enacted, as, among others, the issue of minimum standards, has not been finalized.

Cape Town Energy Strategy: ENERGY VISION 2: A leading African city in meeting its energy needs in a sustainable way, and thus fulfilling its constitutional obligations and global responsibilities.

'Sustainable' implies:

- reducing dependence on non-renewable energy (increasing use of renewable energy, improving energy efficiency)
- reducing harmful environmental impacts of energy production and use (pollution and global warming)

Benefits of being more sustainable include:

- Health benefits (clean air)
- Employment creation (renewable energy generally creates more jobs per GW)
- Increased energy security for city (less dependent on external, centralised sources) and an environmental profile that will enhance competitiveness in investment, trading and tourism

Goals:

- Increasing renewable energy contribution to the energy supply mix (starting with the most financially viable options)
- Improved energy efficiency
- Cleaner air
- Reduced CO_2 emissions

Civil Society:

WWF has a climate change research programme on the resilience of small-scale indigenous ("rooibos") tea farmers to climate change. This project will serve as a demonstration project with a view to building a future research program under WWF and partners on supporting adaptation to climate change in frontline ecosystems and communities.

Climate Action Network:

This network operates nationally and is affiliated internationally. CAN members operate in the mitigation and adaptation fields of climate change. The Western Cape members consist of, amongst others, the following members:

- SouthSouthNorth (SSN)
- Earthlife Africa – Cape Town (ELA-CT)
- Development Action Group (DAG)
- Environmental Monitoring Group (EMG)
- Sustainable Energy Africa (SEA)

The NGOs provide a useful interface with development and climate sectors. NGO's like DAG work in the urban housing sector would need to consider adaptation strategies when developing new housing projects. SSN operates exclusively in the climate sector, having recently started a programme that will investigate both mitigation and adaptation opportunities in South and Southern Africa as they relate to sustainable development and poverty.

Research:

The Energy Research Centre (UCT) has just concluded a study on the cost-benefit analysis of adaptation for the Berg River project.

Climate Systems Analysis Group (UCT) has been involved in the development of regional scale climate change scenarios and capacity building for Africa, as part of the Assessment of Impacts and Adaptation to Climate Change Programme (AIACC). There are a number of other projects including climate change in the water sector and adaptation to climate change among marginal groups.

Business:

Apart from the rise in companies specializing in home water-recycling installations, boreholes and well-points, there does not seem to be evidence of businesses addressing climate change impacts directly but this could be explored further.

Integration of climate change into provincial and municipal planning strategies and frameworks:

There are a number of provincial and municipal documents that outline strategies and frameworks that guide provincial and municipal development. These documents include Provincial Growth and Development Strategy (PGDS), Provincial Spatial Development Framework (PSDF), Integrated Development Plan (IDP) and Spatial Development Framework (SDF). There are numerous other documents that might be addressed to examine how climate change could be integrated. For example, the Water Services Development Plan (WSDP) is required to inform the water strategy of the municipalities and could integrate information about climate variability.

These documents cover a wide range of topics. Climate change does not appear to be explicitly addressed in any of these documents. However, issues relating to climate are addressed. At the same time, there are topics that are covered that do not mention links to climate, despite being impacted by climate. For example the WSDP for the City of Cape Town provides information on the existing water supply options and future alternatives, but no discussion is provided on the uncertainty of the expected rainfall and recharge of the water resources (Geustyn Loubser Streicher and Palmer Development Group, 2001). The DWAF guide on the WSDP provides a comprehensive checklist on the demand and supply of the water, but is also silent on the matter of climate change (DWAF 2004).

If climate change is to be adequately addressed, it is imperative that climate-related issues are flagged in these strategies and frameworks. This can be done in many places, but would require a systematic approach. It is important that stakeholders are involved in the process, as those involved in the sectors are aware of the multiple impacts that climate might have on their sectors. It could be useful to have climate scientists interact with sector stakeholders in order for the stakeholders to be aware of the potential climate impacts.

For example, the Integrated Development Plan (IDP) for City of Cape Town 2005/2006 has a section entitled ‘Managing water supply and demand to meet future need’. They state that,

‘Greater Cape Town is part of a water scarce region with the current drought highlighting the need to implement strategies to increase water supply and reduce consumption.

A new Water Demand Management strategy has been developed in conjunction with the Department of Water Affairs and Forestry (DWAF) to help ensure a long term sustainable approach to water conservation. It will help to achieve our target of a 20% reduction in the projected consumption in 2010. The Berg River Project is well underway and once commissioned in 2007, will provide an acceptable assurance of supply for at least another six years, subject to average rainfall.' (IDP, Cape Town, p. 30)

The role of drought has been acknowledged and this is important, although there needs to be further investigation of how drought frequency might change. The supply of water has been established without addressing the impacts of climate change which could change the precipitation amount and intensity which will affect the incoming water. Increased temperatures will also increase evaporation. On top of this, there is population growth which will increase consumption.

The section on health in this document suggests that increased intensity of rainfall could lead to increased flooding in urban areas. This in turn can lead to ill health through water-borne diseases. This is particularly important in addressing the impact of climate on the most vulnerable, as flooding tends to impact marginal groups living in informal housing. An adaptation measure would be to ensure that the water and sewage system can cope with increased flooding events. In the IDP it is stated that,

'The upgrading of existing infrastructure and provision of new infrastructure to meet urban growth and development pressures is proving to be a financial challenge.'(Pg 30)

Upgrading infrastructure is a challenge even before integrating the potential for impacts of climate variability. This can be expanded to assess the impact on housing, transport, agriculture and other sectors. Therefore, climate priorities need to be on the agenda when allocating finances if adaptation to climate change is to be addressed.

The recently gazetted Disaster Management Framework (2005) emphasizes the threat of climate related hazards,

'South Africa … is exposed to a wide range of weather hazards, including drought, cyclones and severe storms that can trigger widespread hardship and devastation.'(p. 1)

'The national disaster management framework recognises a diversity of risks and disasters that occur in southern Africa, and gives priority to developmental measures that reduce the vulnerability of disaster-prone areas, communities and households. Also, in keeping with international best practice, the national disaster management framework places explicit emphasis on the disaster risk reduction concepts of disaster prevention and mitigation as the core principles to guide disaster risk management in South Africa. The national disaster management framework also informs the subsequent development of provincial and municipal disaster management frameworks and plans, which are required to guide action in all spheres of government.'(Pg. 2)

The framework also emphasizes the need to reduce vulnerability to disasters rather than the traditional response approach. This can be seen as a key adaptation to climate change. They also highlight the need to integrate across all spheres of government. This is particularly important if the vulnerability of local livelihoods is a priority, as the impacts need to be addressed in a holistic manner that covers a range of sectors. A dedicated effort is needed to address issues related to climate change within these documents……."

Reference:

Midgley GF, Chapman RA, Hewitson B, Johnston P, De Wit M, Ziervogel G, Mukheibir P, Van Niekerk L, Tadross M, Van Wilgen BW, Kgope B, Morant PD, Theron A, Scholes, RJ and Forsyth GG 2005. *A status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape.* Report to the Western Cape Government, Cape Town, South Africa. CSIR Report No ENV-S-C 2005-073, Stellenbosch.

Annexure D

National/International policies and interventions regarding Climate Change.

As summarised by Midgley et al (2005).

"……In the growing recognition by the global community of climate change, a number of formal strategic frameworks with relevance to local government and business have been established at the inter-governmental level. Key relevant actions are highlighted below, in each case giving the date of signature and date of ratification by the SA government:

a) United Nations Framework Convention on Climate Change (UNFCCC, see http://www.unfccc.de); signed: 15 June 1993, 27 August 1997; ratified: 29 August 1997.

The United Nations Framework Convention on Climate Change was signed by 154 governments in Rio de Janeiro during the United Nations Conference on Environment and Development (UNCED) in June 1992. The convention addresses the threat of global climate change by urging governments to reduce the sources of greenhouse gases. The ultimate objective of the convention is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system of the world.

b) United Nations Convention to Combat Desertification in Countries Experiencing Serious Droughts and/or Desertification, Particularly in Africa (see http://www.unccd.int**);** signed: 9 January 1995; ratified: 30 September 1997.

This related to the desertification and degradation of land in arid, semi-arid and dry sub-humid areas and does not refer to the expansion of existing deserts. It is caused primarily by human activities, through over-exploitation and inappropriate land use, and by climate variations. The Department of Environmental Affairs and Tourism is responsible for the coordination of the implementation of this convention in South Africa, with the advice from representatives from the non-governmental organisation (NGO) sector.

c) Ramsar Convention - Intergovernmental Treaty which provides a framework for national action and international co-operation for the conservation and wise use of wetlands. The Convention produces a Ramsar list of contracting parties to the Convention on Wetlands of International Importance, (see http://www.ramsar.org**);** Signed: in Iran in 1971..

The Ramsar convention addresses one of the most important issues in South Africa, namely the conservation of the country's water supplies for the use of both the natural and the human environments. South Africa has designated 15 sites to the List of Wetlands of International Importance. A number of others are under consideration. A Wetland Conservation Bill has been proposed which will help South Africa to meet the aims of the convention.

d) Montreal Protocol - Protocol for the Protection of the Ozone Layer

(see http://www.unep.org/ozone/montreal.shtml and http://www-esd.worldbank.org/mp)

Ratified: 15 January 1990

Acceded: 15 January 1990

The protocol is aimed at ensuring measures to protect the earth's ozone layer. South Africa also ratified the subsequent London Amendments to the protocol on 12 May 1992, which were designed to restrict the use of chlorofluorocarbons (CFCs) and halons. Parliament has approved the ratification of the Copenhagen Amendments to the Protocol and the necessary steps are now being taken for the instrument for ratification to be deposited. South Africa has, however, acted in full compliance with these amendments…".

Reference:

Midgley GF, Chapman RA, Hewitson B, Johnston P, De Wit M, Ziervogel G, Mukheibir P, Van Niekerk L, Tadross M, Van Wilgen BW, Kgope B, Morant PD, Theron A, Scholes, RJ and Forsyth GG 2005. *A status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape.* Report to the Western Cape Government, Cape Town, South Africa. CSIR Report No ENV-S-C 2005-073, Stellenbosch.

Annexure E

Mitigation actions for reducing carbon emissions per sector (from IPCC 2007).
The sectors are listed in order from top to bottom where cost-effective reductions can be achieved.

Sector	**Current mitigation technologies**	**Future potential for mitigation**
Building	Efficient lighting; more efficient electrical appliances; better insulation and ventilation; solar-powered heating/cooling; alternative refrigeration fluids; recovery and recycling of fluorinated gases	Integrated soar voltaic electricity; smart metering, intelligent controls
Industry	More efficient electrical equipment, heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions	Advanced energy efficiency; CCS* for cement-, ammonia- and iron manufacture; inert electrodes for aluminium manufacture
Energy supply	Improved supply and distribution efficiency; combined heat-and power systems; switching from coal to gas; nuclear power; renewable heat and power; CCS techniques	CCS for gas; biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable including tidal and wave energy
Agriculture	Improved land management; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques/livestock and manure management to reduce methane emissions; improved nitrogen fertiliser application, replace fossil-fuel use with dedicated energy crops	Improvement of crop yields
Forestry	Forest management; new forestation; reforestation and reduced forestation; harvested-wood product management; use of forestry products for bio-energy to replace fossil-fuels	Tree-species improvement to increase biomass productivity and carbon sequestration; improved remote-sensing technologies for analysis of vegetation/soil-carbon sequestration potential and mapping land-use change
Transport	More fuel-efficient, hybrid vehicles; cleaner diesel; bio-fuels; shift from road- to rail and public transport systems; more cycling/walking; land-use and transport planning	Second-generation bio-fuels; more efficient aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries.

- carbon dioxide capture and storage

Summarised from http://www.ipcc.org